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2015: THE BEST EVER YEAR FOR SCIENCE?

From rivers on Mars to designer humans, the breakthroughs that changed the way we see the world

PLUS

STAR WARS FICTION MADE FACT

- ▶ Artificial gravity
- ▶ Hyperspace travel
- ▶ Humanoid aliens

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ORIGINS OF LIFE
How chemicals became creatures

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WILL GET CHRISTMAS
JINGLES OUT OF
YOUR HEAD**

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The ignored wild places protecting our climate

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26-hour surgery revealed

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WELCOME



1915 WAS A fantastic year for science. Albert Einstein, who graced last month's cover, published his General Theory of Relativity, a paper that described the threads making up the fabric of our Universe. 1859 wasn't bad, either: that was the year Charles Darwin gave us *On The Origin Of Species*, an idea so profound it made humanity rethink its place in the world. And then there was 300BC, when Euclid established geometry as we know it today – a simple tool that's still essential to our efforts to explore our Universe.

Of course, nothing in 2015 could quite touch these seismic breakthroughs. But still, this year it seemed like barely a week went by without news of another 'world first' hitting our desks. Rosetta found oxygen – a crucial ingredient for life – on comet 67P, liquid water was discovered on Mars and New Horizons brought us Pluto's icy vistas. And that was just in space; back on Earth, quantum teleportation records were smashed, a ferret was saved from extinction and the first human genes were edited.

And all of the above made headline news – science is now at the top of the national agenda like never before. So join us in a look back at one of the most exciting years for science in living memory.

Have a great Christmas!

Daniel Bennett

Daniel Bennett, Acting Editor

PS Don't miss our January issue, on sale 7 January 2015



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THIS MONTH WE...



...chowed down on a burger made of mealworms when we paid a visit to Grub Kitchen in Pembrokeshire – the UK's first insect restaurant. Read about it at bit.ly/1P9D0Kz

...went for a spin in the new Tesla Model S. We were testing out the new autopilot feature, which makes it almost self-driving – but it was the face-melting acceleration that impressed us the most.



...dispatched Picture Editor James to the Wellcome Image Awards, where he was one of this year's judging panel. We'll bring you some of the winning pictures very soon...

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APPEARING IN THIS ISSUE...



Brian Clegg

Brian is author of over 20 popular science books. This month he's in a reflective mood as, starting on p32, he takes a look back at some of 2015's greatest scientific breakthroughs.



Jheni Osman

Jheni is a science writer, TV presenter and former *Focus* editor. Starting on p42, she looks at some less talked-about ecosystems that are vital for life on Earth.



Hayley Birch

Science journalist Hayley is co-author of the book *Big Questions In Science*. On p58 she looks at the annoying phenomenon of 'earworms' – tunes that get stuck in your head.



Tim Peake

Tim is a cross-country runner and former army test pilot. Oh, and the first British astronaut to be sent to the International Space Station! Read our interview with him on p52.



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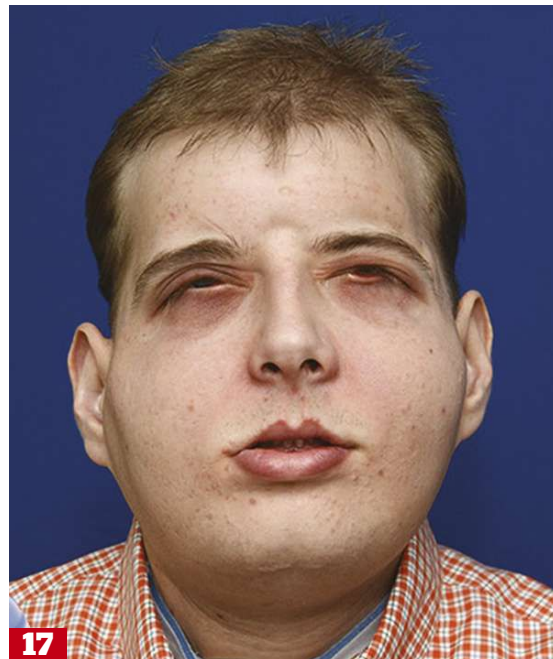
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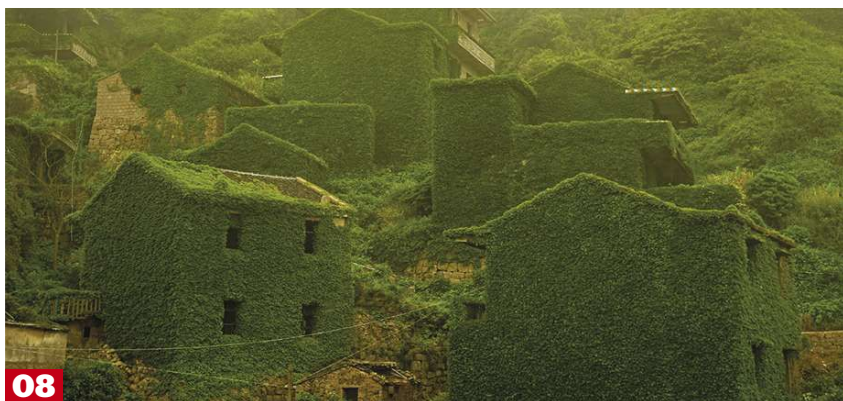
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Awe-inspiring images from the world of science

MegaPixel

Greenhouses

THE BUILDINGS OF Gouqi Island are slowly being consumed by a thick blanket of green. The island is located a few hours east of Hangzhou Bay in eastern China, and was once home to a thriving fishing community. But as the shipbuilding and tourism industries grew, the village became deserted. With nobody left to maintain them, the buildings were soon reclaimed by the natural world.

"These buildings are covered with *Parthenocissus tricuspidata*, a relative of the grape vine and Virginia creeper. It's native to China but is also widely cultivated as an ornamental climber for its red autumn foliage," explains Dr Alastair Culham, Curator of the University of Reading's herbarium. "The climber was probably already planted there to decorate the houses. It's equivalent to ivy in the UK, which will soon cover a building if left alone."

PHOTO: GETTY





MegaPixel

Failure to launch

ALTHOUGH THEY BEAR a striking resemblance to the Space Shuttle, the two craft gathering dust inside this gigantic hangar have nothing to do with NASA. This is a pair of Buran-class orbiters developed by the USSR during the late 1970s and 80s.

The Buran (Russian for blizzard) programme was initiated in response to NASA's success with the Space Shuttle. The Soviet Union was concerned that NASA's newest vehicle might be used for military purposes, which drove it to build an equivalent of its own. The Russians didn't want a vehicle that mirrored the Shuttle so closely, but aerodynamic analysis showed that the US design was almost ideal.

The one and only time a Buran orbiter took off was during an unmanned test flight on 15 November 1988. The remote-controlled vehicle made two orbits of Earth before landing at Kazakhstan's Baikonur Cosmodrome.

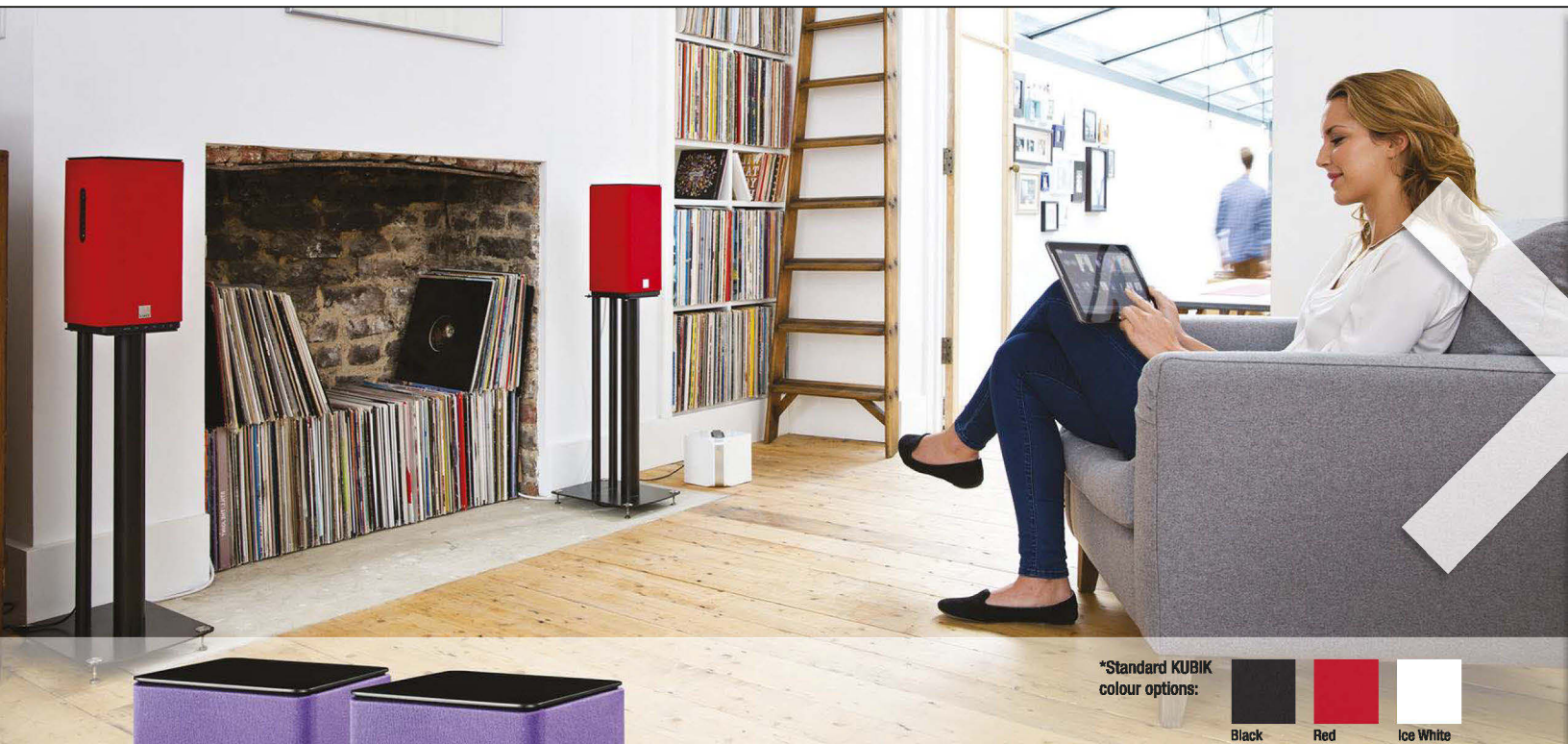
Four more Buran orbiters and a host of full-scale test models were under construction during that maiden flight, two of which can be seen here – the Ptichka (Little Bird) shuttle in the foreground with one of the test models behind. They were never completed because the fall of the Soviet Union in 1991 led to the cancellation of the Buran programme and the orbiters were left to ruin.

PHOTO: S DMITRII ANATOLEVICH

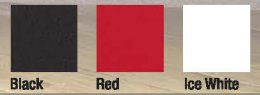


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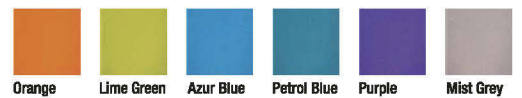


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REPLY

Your opinions on science, technology and *BBC Focus Magazine*

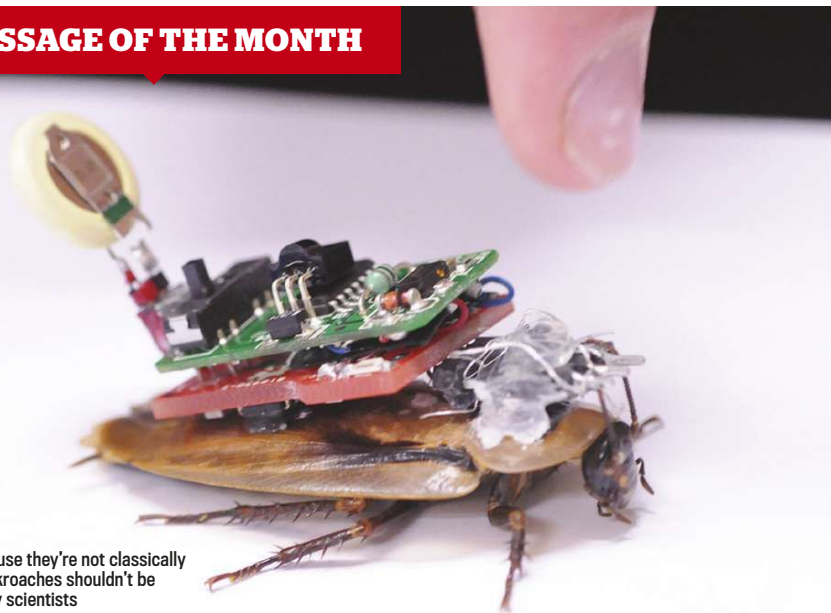


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MESSAGE OF THE MONTH



Just because they're not classically cute, cockroaches shouldn't be abused by scientists

A question of ethics

WHILE READING YOUR December issue I started thinking about the ethics of some research experiments. While the results of the experiments are very interesting, where do scientists draw the line?

The cadaver arms used to "throw punches" on p30 are one example. Would this sort of experiment be acceptable in all countries? Would the deceased and their families be made aware that this sort of experiment would be 'done' on their bodies?

Then I read about controlling the movement of cockroaches using electrodes. While I am not overly keen on bugs, I wondered how far this technology could be taken? Could large animals be experimented on? Would it be wrong to do this to humans? And what if the technology got into the wrong hands (like a baddie in James Bond!)? Are ethics in science regulated globally or do different countries have different guidelines?

Abigail Harrison, via email

Ethics can vary from region to region. Generally speaking, once a person has agreed to donate their body to science, they can become anything from an organ donor to a cadaver for medical students – an invaluable teaching tool. As for large-scale cyborg creatures, that kind of technology is likely to remain the remit of Hollywood villains... we hope. – Ed

AI, You're OK

Hurrah! At last someone who shares my views. I was delighted to read the sentiments of Kevin Surace (December, p54) regarding the impact of artificial intelligence on humankind. I have been banging on about this for years. When will the powers that be wake up to the inevitable fact that working for a living will become obsolete due to automation?

The question is: what are we going to do about it? When working for a living becomes outmoded and, as radical as it may seem, money also becomes redundant, would the class system we live in now disappear? Maybe I could even get a free copy of *Focus*!

Whatever happens, something needs to change to accommodate the advent of AI. Hopefully that change of mindset will benefit all of us. In any case, I'm glad Kevin Surace was able to get his views out in your magazine, so maybe someone of clout can further this issue. This problem needs more than thought, it needs action!

Alexander M Sutherland, Banffshire

A working solution

The article on the end of work (December, p53) was interesting. I have never been concerned that self-replicating super-robots will wipe out the human race. What does worry me is in the not too distant future people could become 'redundant'. Virtually all jobs can be replaced. If something can be taught, then machines can learn to do it better. Not just manufacturers, but accountants, doctor and lawyers (the list is endless) can all be replaced by machines that will perform their tasks more efficiently. For the moment, new research (helped by machines) and original ideas used to develop new theories appear to be protected from automation, but even that might not be safe if Andrew Lea's ideas on developing a 'Theory of Thinking' came to fruition.

We need to develop a strategy to deal with the problem. Since development tends to be exponential, the crunch will not be in a century but within 20 or 30 years. The outcome does not have to be bad, the potential for good is enormous. It

Write in and win!

The writer of next issue's Message of the Month wins a cool-looking Minirig speaker, worth £139.99. It offers up to 50 hours of battery life and a powerful 15W amp. It's Bluetooth 4.0 and APT-X compatible, and even comes with a unique cable to let you charge your other gadgets. minirigs.co.uk



will, however, require clever thinking to work a way through it.

Geoff Dunwell, Maidenhead

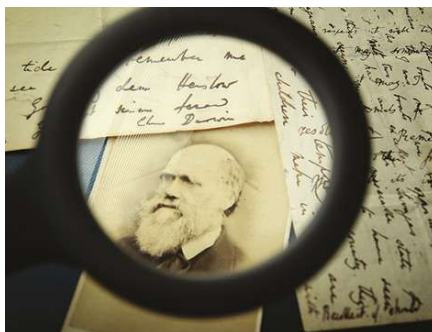
Relatively correct

In your article 'Relativity on trial' (December, p38), I wonder if Marcus Chown's comment about Isaac Newton being 'wrong' was a little ungracious. Like all great thinkers, Newton opened a window onto vistas of understanding that in turn revealed new questions. Don't forget, this happened in a time when gruesome public executions drew crowds.

His conclusions proved invaluable to the understanding of our everyday world. Although, yes, he did also delve into alchemy and other dubious areas.

And of course, Charles Darwin published his own immensely influential masterwork, with no knowledge of genetics. But it still stimulated advances in evolutionary science without needing – or claiming – to be 100 per cent right.

We may, I suppose, accuse the great Einstein of being wrong when in 1935 he dismissed quantum entanglement and non-locality as nonsense – concepts since proven scientifically sound. No-one is



Darwin's theories revolutionised evolutionary biology

perfect. No scientist should ever claim to be. And are there not a few cracks opening in the Big Bang theory?

Jeff Clarke, Brixham

One ocean

David Shukman's article on plastic bags (December, p23) illustrates the fact that such labels as North Sea, English Channel and Atlantic Ocean are meaningless.

There is only one ocean, one atmosphere, one biosphere, and for the foreseeable future, one Earth. The actions of the individual affect everyone.

Derek Staff, Oxfordshire



Derek Staff says that plastic waste is a global problem that we should all work to solve

FOCUS

SCIENCE AND TECHNOLOGY

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DISCOVERIES

News and views from the world of science

EDITED BY
JASON GOODYER



TYPHOON WARNING

When the flood waters are rising, we can now call on NOAH for help

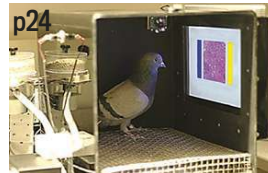
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LIGHT OUT OF DARKNESS

Black hole is spotted emitting a bright flare of X-ray light

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PIGEON POWER

How these urban birds could help in the battle against cancer

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THE BIG STORY

WORLD'S MOST EXTENSIVE FACE TRANSPLANT

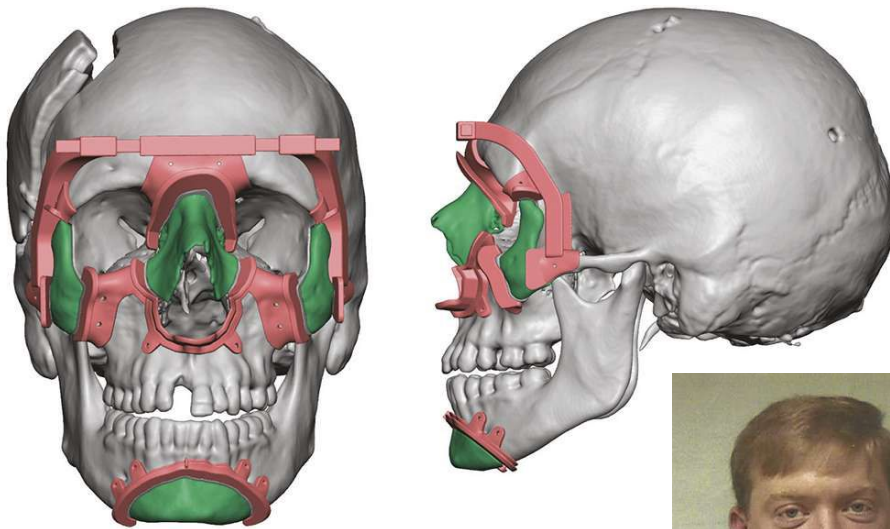
Plastic surgeons in the USA have successfully completed the most complicated face transplant to date

A TEAM OF SURGEONS in New York have successfully transplanted the scalp, forehead, face, ears and eyelids of a donor – as well as muscles, nerves and blood vessels – onto 41-year-old volunteer firefighter Patrick Hardison.

Hardison was badly injured when a burning home collapsed on him. He lost his ears and all of his hair, and was left with major facial scarring and disfigurement. Despite undergoing more than 70 operations, he was still unable to return to a normal life. In 2014 he was put on a waiting list for a donor that matched his skin tone, blood type and skeletal structure. →

Patrick Hardison before and after the transplant

PHOTO: NYU LANGONE MEDICAL CENTER



➔ A match was eventually found when 26-year-old David Rodebaugh was declared brain dead after being involved in a cycling accident.

“When I met Patrick and heard his story, I knew that I had to do all that I could to help him, and every member of my team felt the same way,” said Eduardo Rodriguez, who led the surgical team. “His surgery sets new standards in facial transplantation and will serve as an amazing learning tool. I am particularly encouraged with the success we have achieved in transplanting David’s eyelids and blinking mechanisms to Patrick. This is a major milestone, one that could lead to preserving vision in future patients.”

During the face transplant Rodriguez removed the donor’s face and scalp, including the outer skin, tissue, nerves and muscle, as the surgical team removed the skin on Hardison’s face. Rodriguez then placed the donor face on Hardison and connected the blood vessels. In order to ensure the transplanted tissue was as precise a fit as possible, the team used CT scans and 3D computer modelling techniques to build custom 3D-printed cutting guides.

Signs of success were already apparent in the final hours of the operation: colour returned to Hardison’s face, indicating that blood was circulating into the tissue. Hardison is now undergoing physical

Above: 3D scans showed the surgeons where to cut
Right: Hardison before the fire (right)
Below: Hardison with Rodriguez after the face transplant



therapy to build his strength and stamina and to enhance his ability to speak. He will also have to take medication to prevent his body from rejecting the transplant.

“I am deeply grateful to my donor and his family,” Hardison said. “I hope they see in me the goodness of their decision. I also want to thank Dr Rodriguez and his amazing team. They have given me more than a new face – they’ve given me a new life.”

TIMELINE

A history of face transplant surgery

2005

Isabelle Dinoire (pictured) is mauled by her dog after an accidental sleeping pill overdose. She is the first person to receive a transplant of living nose and mouth tissue.



2008

American Connie Culp receives a near-full face transplant, including bone, muscle, skin, blood vessels and nerves, after being shot in the face by her husband.

2010

A team of 30 Spanish doctors carry out the first full face transplant on a man injured in a shooting accident.

2012

Turkish surgeon Omer Ozkan performs a full face transplant on 19-year-old Ugur Acar, who was badly burnt in a house fire as a baby.

GOOD MONTH/ BAD MONTH

It's been good for:

GYM BUNNIES

LOOKS LIKE IT'S time to hit the treadmill. Older adults who take moderate exercise have thicker cortices, the outer layer of the brain that typically atrophies in cases of Alzheimer's disease, researchers at the University of Maryland have found.

COFFEE DRINKERS

MAKE MINE AN espresso. A study at Harvard University has found that drinking two or three cups of coffee a day may reduce the risk of Type 2 diabetes and cardiovascular and neurological diseases.



It's been bad for:

SHARKS

IT SEEMS THAT climate change is just as bad news for sharks as it is for humans. Increasing sea temperatures lead to the fish becoming hungrier, but increased levels of carbon dioxide in the water are interfering with their ability to locate food via scent, researchers at the University of Adelaide have found.

PHOBOS

NASA has found that the long shallow grooves that can be seen

running along the surface of Mars' biggest moon are 'stretch marks' caused by gravitational forces pulling it apart. The moon will eventually disintegrate, say the researchers.



Could NOAH save the Philippines from flooding?

DAVID SHUKMAN
The science that matters



MY FIRST IMPRESSION of being in a typhoon was that it felt like warm buckets of water were being chucked over me. It made British storms look amateur. I was soaked through in seconds.

I was in the Philippines, an island nation that lies in the path of a typhoon production line fed by the warm waters of the Pacific Ocean, in late October just as Typhoon Koppu hit. The producer and I struggled with umbrellas above the cameraman who was desperate to save his lens.

The winds were powerful enough to knock down trees but it was the sheer scale of the downpour that did most damage. A staggering metre of rain fell in a couple of days. Roads became rivers.

There were casualties, but the death toll, which could have run into the thousands as in previous typhoons, was kept to low double figures. Good forecasting was key. Satellite images had spotted the distinctive tight spiral of the storm. Computer models suggested a likely path. And word of the danger quickly spread on Facebook and Twitter. This gave people a chance to get ready. A generation ago, the technology



did not exist to make this kind of early warning possible.

But it's one thing to raise the alarm, quite another to forecast exactly which areas will be hit. The typhoon that we reported on followed the predicted track. Yet it caused flooding where none had been expected because intense rain in the hills made its way downstream into the cities.

There is an effort to deal with this. A project called NOAH, backed by a host of international experts including Britain's Environment Agency, is using airborne Lidar (a form of remote-sensing technology) to generate detailed terrain maps to better understand future water flows.

It cannot come soon enough. At a local weather station, we

found a pair of bedraggled forecasters. They had thought the storm was missing them, only for sudden flooding to wreck their instruments. They smiled at the irony and one told me: "Let's hope we can be in better shape for the next one."

DAVID SHUKMAN is the BBC's Science Editor. @davidshukmanbbc

WHO'S IN THE NEWS?

Opeyemi Enoch

Who's he?

A mathematics professor based at the Federal University of Oye-Ekiti in Nigeria who claims to have solved the Riemann Hypothesis.

Hang on. Riemann what?

It's a notoriously tricky mathematical problem that was proposed by German polymath Bernhard Reimann back in 1859. It involves the distribution of prime numbers, those only

divisible by themselves and one. Enoch claims to have the solution, though as he is yet to publish his proof not everyone is convinced he is correct.

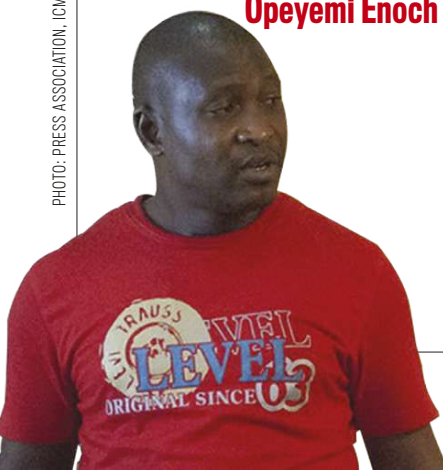
Why is it so important?

The Riemann Hypothesis is one of the seven so-called Millennium Prize Problems set by the Clay Mathematics Institute in 2000. The problems are so fiendishly difficult that the institute decided to offer

\$1m to the first person to solve one of them.

I fancy having a crack. Are there any still unsolved?

If Enoch has solved the Riemann Hypothesis, that leaves five of the original seven still unsolved: P versus NP, the Hodge Conjecture, the Yang-Mills Existence, the Navier-Stokes Existence and the Birch and Swinnerton-Dyer Conjecture. Good luck.



1 MINUTE EXPERT

Molecular 'Death Clock'



That sounds nasty. What is it?

It is the name for the processes inside cells that generate genetic mutations at a constant rate. They were discovered by researchers at the Wellcome Trust Sanger Institute.



Tell me more.

Every cell in the human body contains a copy of the human genome. Over the course of a lifetime, cells acquire mutations in their genomes. Some of these occur in bursts thanks to external factors such as smoking or exposure to sunlight. However, researchers have now found two types of mutation that correlate with age, suggesting that they are constantly 'ticking away'.



Is that a bad thing?

Probably. The researchers think that these processes could be responsible for a large number of human cancers and may contribute to human ageing.



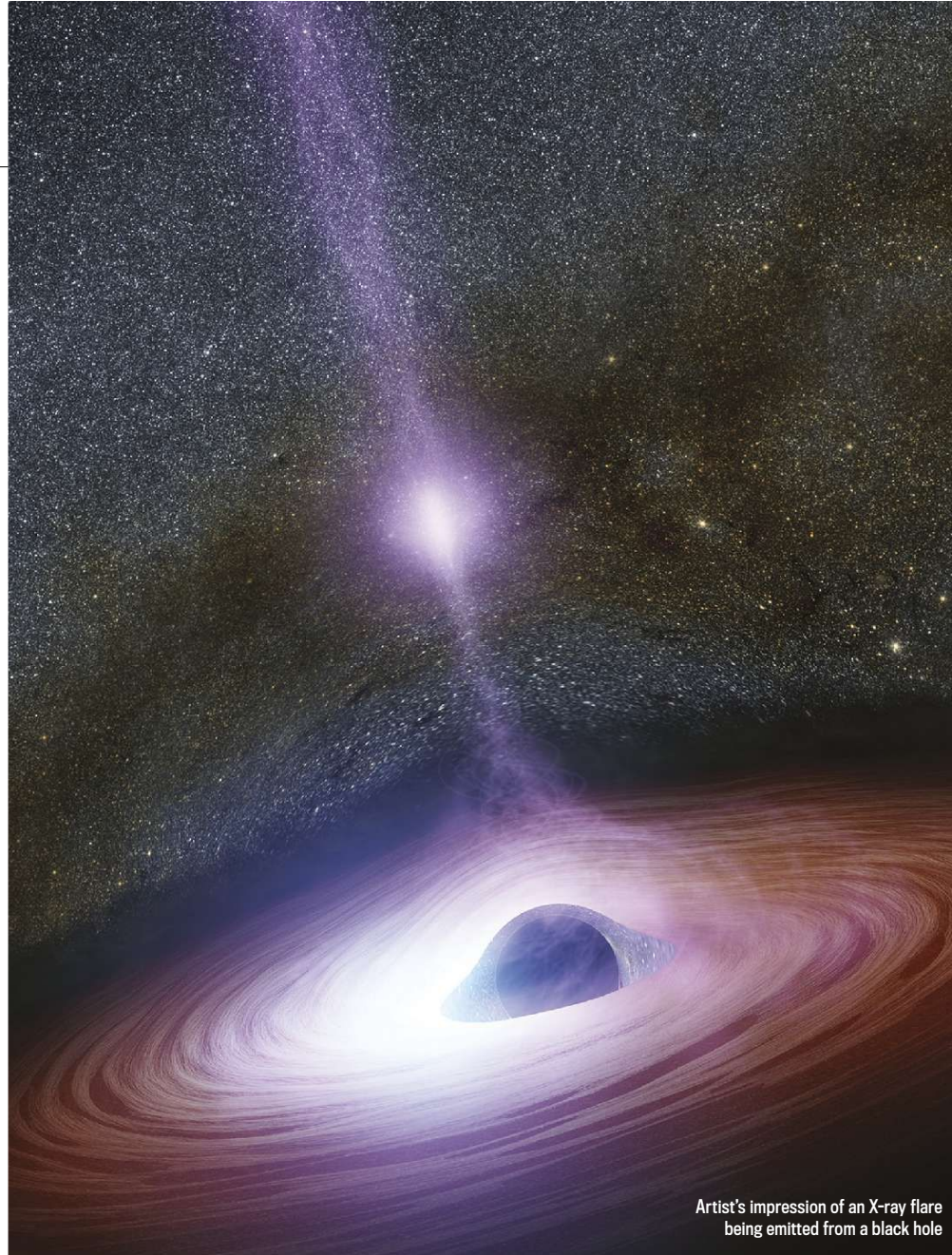
Are there any practical implications?

Thanks to its constant rate, the process could help cancer researchers to predict how quickly a cancer can grow or spread to other parts of the body.



Cells obtain mutations that may cause ageing

PHOTO: NASA/JPL-CALTECH, JOLYON TROSCIANKO, BREUER LAB/BROWN UNIVERSITY, GENOME RESEARCH LTD



Artist's impression of an X-ray flare being emitted from a black hole

SPACE

Black hole has dramatic flare

DESPITE BEING AMONG the darkest objects in the Universe, black holes are still capable of producing some of the brightest events.

NASA's Swift and the Nuclear Spectroscopic Telescope Array (NuSTAR) space telescopes have successfully captured Markarian 335, a supermassive black hole located 324 million light-years away in the direction of the constellation Pegasus, spewing out a gigantic flare of bright, energetic X-ray light.

The finding suggests that supermassive black holes send out enormous beams of X-rays when their coronas, sources of extremely energetic particles that surround them, are ejected.

"This is the first time we have been able to link the launching of the corona to a flare," explained lead author Dr Dan Wilkins from Saint Mary's University in Canada. "This will help us understand how supermassive black holes power some of the brightest objects in the Universe."

In September 2014, Swift and NuSTAR recorded a huge flare jetting out of Markarian 335 for several days. Careful analysis showed the corona being ejected from the black hole and eventually collapsing. Exactly why this occurs is not understood.

"The nature of the energetic source of X-rays we call the corona is mysterious, but now with the ability to see dramatic changes like this we are getting clues about its size and structure," said NuSTAR's Fiona Harrison.

THEY DID WHAT?

Scientists eavesdrop on crows' conversations

What did they do?

Researchers from the Universities of Bath and St Andrews fitted spy tags to a group of 41 crows in the remote island of New Caledonia in the South Pacific and recorded their interactions. They then placed a log full of wood-boring beetle grubs within

easy reach of the crows and again observed their behaviour.

Why did they do that?

Crows are one of a handful animals capable of using tools. The team wanted to see how crows share knowledge and skills with one another.

What did they find?

When the crows were presented with a ready food source, like the beetle grubs, they congregated around it. This increased the spread of information between them. The researchers likened the effect to office workers gossiping around a water cooler or coffee machine.



"And I said to her that the boss is being an idiot"

ENGINEERING

Solved: how bats land upside down

BATS ARE FAMOUS for hanging upside down when sleeping or resting. But in order to get into this position they have to perform a mid-air flip that would put even the most agile trapeze artist to shame. Quite how they manage to do this has baffled scientists. However, biologists at Brown University think they finally have the answer.

"Bats land in a unique way," said researcher Prof Sharon

Swartz. "They have to go from flying with their heads forward to executing an acrobatic manoeuvre that puts them head down and feet up. No other flying animal lands the same way as bats do."

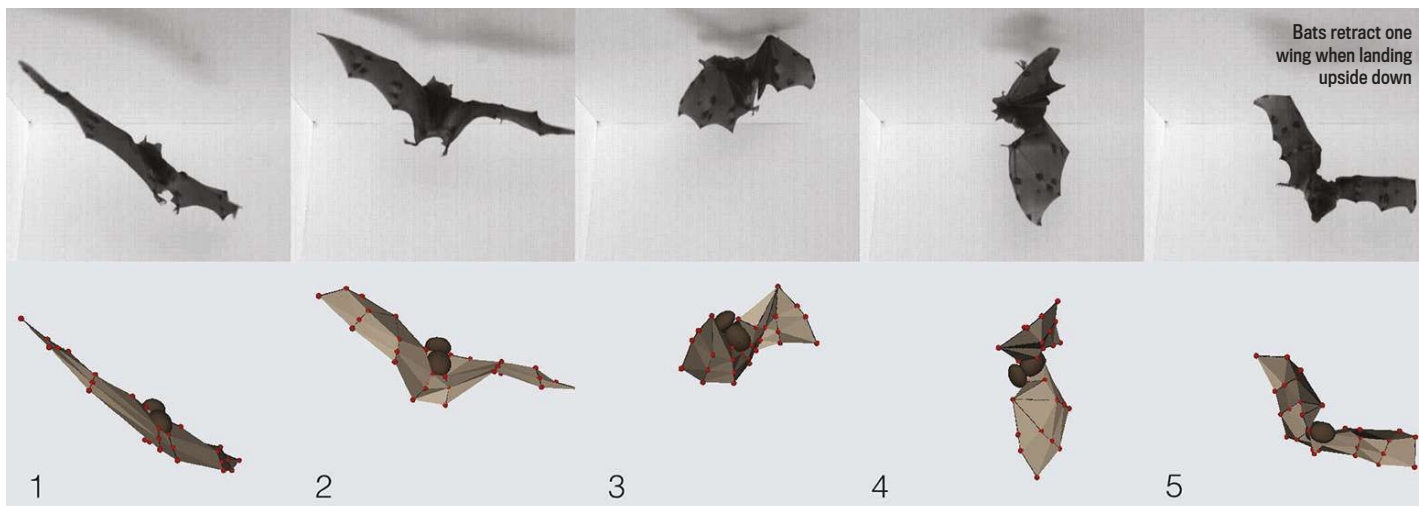
To investigate the intricate manoeuvre, the team rigged up a high-speed camera and recorded two species of bats, Seba's short-tailed bats and lesser dog-faced fruit bats, as they landed on a piece of

mesh attached to the ceiling of an enclosure.

Bats have the heaviest wings compared to bodyweight of any flying animal, and it turns out this extra weight helps them perform their aerobatic moves. As they approach to land, they slightly retract one wing while flapping the other at full extension. This results in the animals rotating in the air in much the same way as Olympic high divers.

As well as answering an age-old question, the finding may be useful in the development of man-made flying machines.

"From an engineering perspective, there's a lot of interest in drones and flying microvehicles," co-author Prof Kenny Breuer explained. "Manoeuvring or directing those robotic vehicles is a challenge. The idea here is that using redistribution of mass is not a bad approach to take."

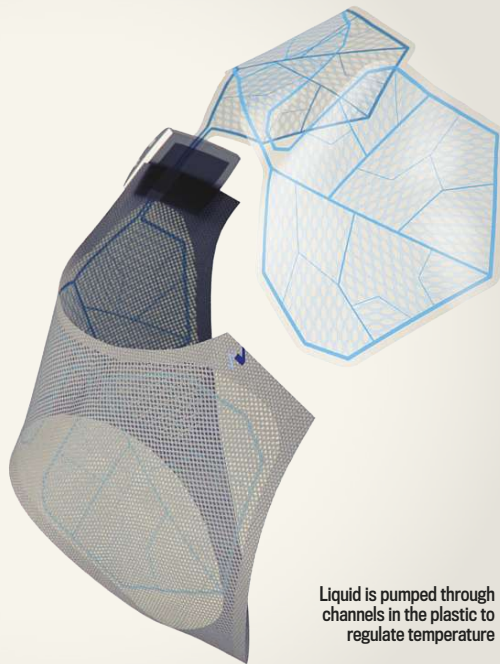


10 DISCOVERIES THAT WILL SHAPE THE FUTURE

BY GRAHAM SOUTHRN

10 Air-con coat

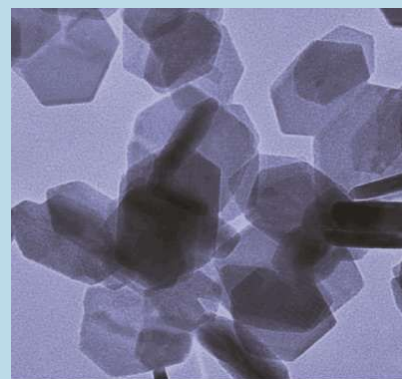
IMAGINE A JACKET that could warm or cool you to a precise temperature. Thanks to a method of mass-producing plastic film containing tiny channels, developed at Finland's VTT Technical Research Centre, you may soon be wearing one. **The film can be added to clothing, then hot or cold liquid can be pumped through the channels.** The team calls the technology 'smart fabric', and the temperature can be selected with the aid of a smartphone. Certainly beats bundling yourself in woollies during the winter months.



Liquid is pumped through channels in the plastic to regulate temperature

9 Smartphone pollution sensor

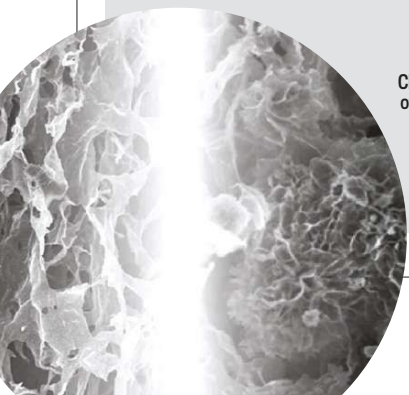
WORRIED ABOUT INHALING nitrogen dioxide from diesel engines? Your smartphone could one day help you avoid it, thanks to a new sensing method developed by scientists at Australia's RMIT University. **The method uses flakes of tin disulphide, which absorb molecules of nitrogen dioxide. The flakes are a few atoms across, and could be placed into a sensor small enough to hold in your hand or build into a phone.** The team says their method is cheaper and more sensitive than existing detectors.



The tin disulphide flakes are sensitive to nitrogen dioxide

8 The ultimate battery

WANT AN ELECTRIC car you can drive from London to Edinburgh on a single charge? Well, it's coming. At the University of Cambridge, **scientists are aiming to build a so-called 'lithium-air' battery capable of storing 10 times more energy than a lithium-ion battery** and costing only one-fifth as much. Currently, the prototype has a graphene electrode that works in pure oxygen – a version that works in air is a decade away.



Close-up image of the battery's structure

7 LEDs from food waste

ENERGY-SAVING LIGHT bulbs and TVs contain LEDs, which produce light from crystals called 'quantum dots'. At the University of Utah, **scientists have learned how to make quantum dots from food waste – specifically, chemicals in discarded pieces of bread, tortilla and soft drinks. The goal is to produce more environmentally friendly LEDs than those made from cadmium selenide, which is toxic when it breaks down.**



6 Self-healing concrete

A TEAM AT Cardiff University is testing types of self-healing concrete, which could reduce the annual £40bn bill for repairing roads and buildings. When embedded sensors detect damage, they trigger a mechanism to repair it. Either shape-shifting materials move within the concrete, or bacteria produces calcium carbonate to fill the cracks.



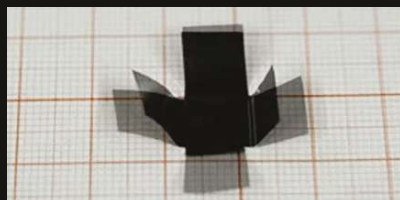
Test walls have been built from the self-healing concrete

5 Climate-saving bacteria

THE ENZYMES PRODUCED by the bacterium *Thiomicrospira crunogena* could help in the fight against climate change. The bacterium lives at the bottom of the sea and its enzymes convert carbon dioxide to bicarbonate. They can operate at the high temperatures and pressures found in industry.

4 Self-folding paper

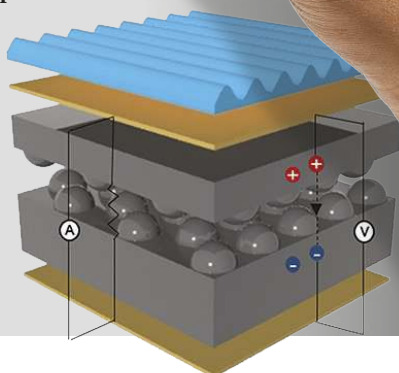
TINY ROBOTS AND artificial muscles are just two potential applications of this self-folding paper made from graphene oxide. It folds in response to heat or light, allowing it to 'walk' and can support objects up to five times its weight.



The graphene box folds up when exposed to light

2 Artificial skin

ROBOTS WILL SOON be able to feel sensations in their fingers, thanks to an electronic skin developed at Ulsan National Institute of Science and Technology in South Korea. The e-skin mimics the grooves on human fingertips and can detect both heat and pressure simultaneously. It's sensitive enough to detect the weight of a single human hair and, worn on a human wrist, the tiny change in temperature caused by blood vessels dilating.



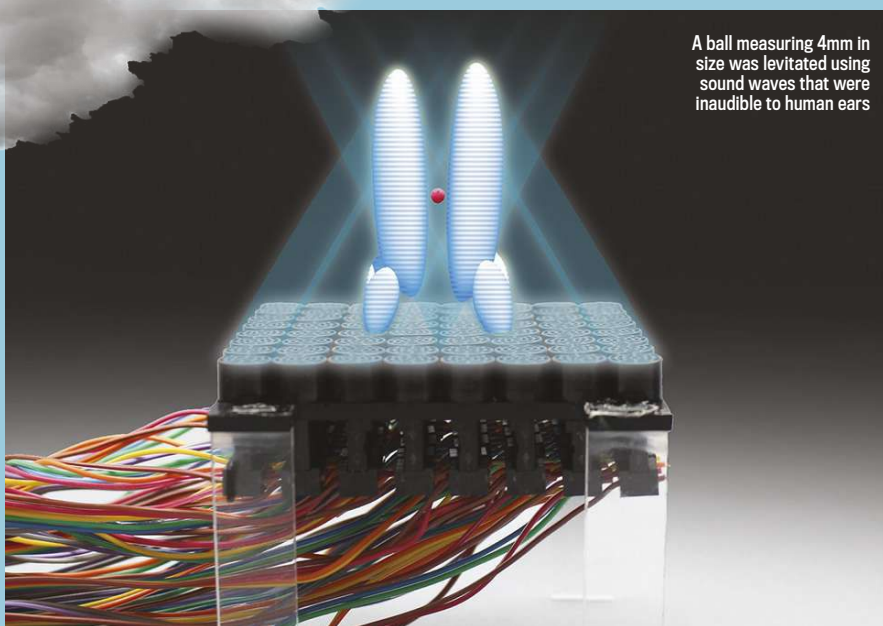
The electronic skin is made up of a ridged surface and interlocking layers - just like real skin



3 Sonic tractor beam

THE TRACTOR BEAM in *Star Trek* wasn't so far-fetched after all. Bristol and Sussex universities have built one that uses sound to move small objects without physically touching them. It could be used to assemble miniature products on a floating production line or

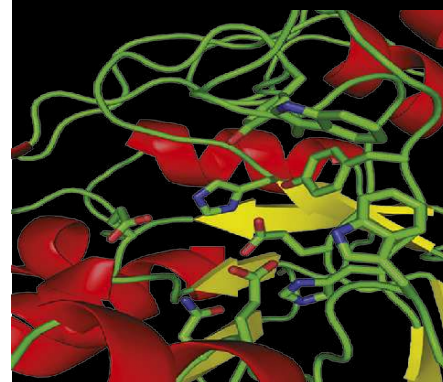
to guide drug-delivery capsules through your body. It works by surrounding objects with high-intensity sound from an array of 64 tiny loudspeakers. The loudspeakers generate acoustic force fields, which are manipulated to pick up an object and then move, hold or rotate it.



A ball measuring 4mm in size was levitated using sound waves that were inaudible to human ears

1 Cancer protein in 3D

THE FIRST 3D image of a protein linked to cancer could help pave the way for new treatments for the disease. The image shows an enzyme known as a bacterial heparanase. Humans have an enzyme with the same function, which is overexpressed in cancers.



MEDICINE

Pigeons can spot cancer on medical images 'as well as humans'

IT SEEMS PIGEONS may not be so bird-brained after all. A team at the University of California, Davis has trained the birds to pick out cancerous breast tissue on mammograms.

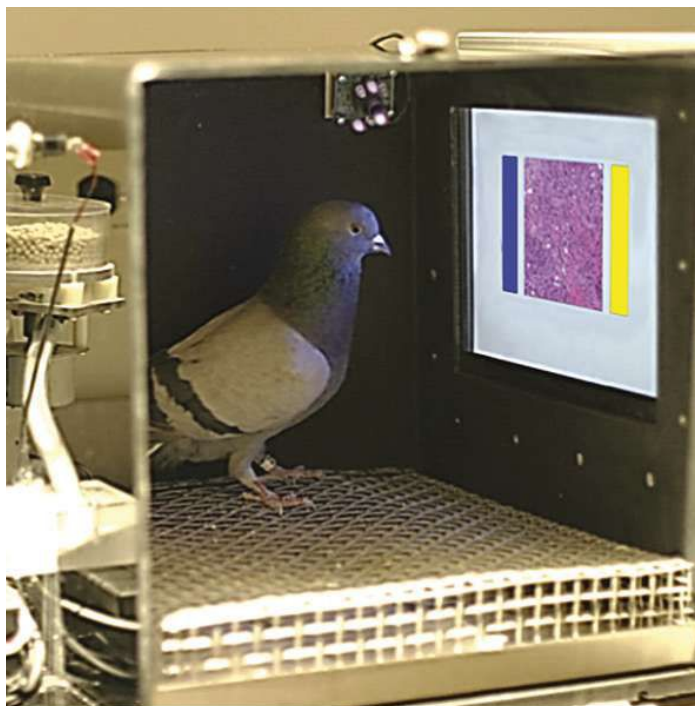
After two weeks of training, using food as motivation, the pigeons were able to correctly identify cancerous tissue 85 per cent of the time. This is a level of accuracy similar to that of human radiologists.

"Research over the past 50 years has shown that pigeons can distinguish identities and emotional expressions on human faces, letters of the alphabet, misshapen pharmaceutical capsules, and even paintings by Monet vs Picasso," said co-author Edward Wasserman. "Their visual memory is equally impressive, with a proven recall of more than 1,800 images."

Even after years of training, physicians can sometimes struggle to correctly interpret mammograms. The process is also time-consuming, labour-intensive and expensive.

Though it's unlikely you will ever be booking an appointment with a pigeon GP, lead researcher Prof Richard Levenson believes that the common birds could play a part in further developments in imaging and display technologies.

"Pigeons' sensitivity to diagnostically salient features in medical images suggests that they can provide reliable feedback on many variables at play in the production, manipulation, and viewing of these diagnostically crucial tools, and can assist researchers and engineers as they continue to innovate," he said.



The pigeon will see you now...

EARTH

Water has been on Earth all along



Lava samples offered the teams pristine examples of the water present when Earth formed

THE EARTH IS known as the Blue Planet for good reason: liquid water covers more than two-thirds of its surface. But exactly how it got there has always been a bit of a puzzle. The question at the heart of the mystery is: was water present when the planet formed 4.5 billion years ago or did it arrive later, perhaps carried here by comets and meteorites?

Now, researchers at the Universities of Glasgow and Hawaii have found evidence that suggests water has been on the Earth since its formation.

The team used an ion microprobe to analyse tiny amounts of water held within a collection of primitive rocks known to have formed deep within the Earth's mantle. Different Solar System bodies

have distinct ratios of hydrogen to deuterium (heavy hydrogen) in their water, so by measuring this, the researchers were able to determine its origin.

"We found that the water had very little deuterium, which strongly suggests that it was not carried to the Earth after it had formed and cooled. Instead, water molecules were likely carried on the dust that existed in a disk around our Sun before the planets formed," said researcher Lydia Hallis.

"Over time, this water-rich dust was slowly drawn together to form our planet. Even though a good deal of water would have been lost at the surface through evaporation in the heat of the formation process, enough survived to form the world's water," she added.



ROBERT MATTHEWS ON YER BIKE!

Scientists can sometimes be pretty unforgiving of mistakes

THE ROYAL INSTITUTION (RI) Christmas Lectures are a fine tradition, right up there with carol concerts and eating too much turkey. But one has always stuck in my memory, and to my amazement it's turned up on the RI's online video archive.

That's not because of its age – though it is over 40 years old – but because it caused the RI huge embarrassment. I still remember being dumbstruck by what Prof Eric Laithwaite demonstrated before his wide-eyed audience of youngsters. In classic Christmas Lecture style, he set up various experiments to illustrate scientific phenomena. His aim wasn't to bore on about some esoteric concept, but to show there was something fundamentally wrong with Newton's laws of motion.

The experiments involved gyroscopes, and Laithwaite showed how these spinning contraptions refused to follow expectation. In some cases, they even appeared to turn into antigravity machines.

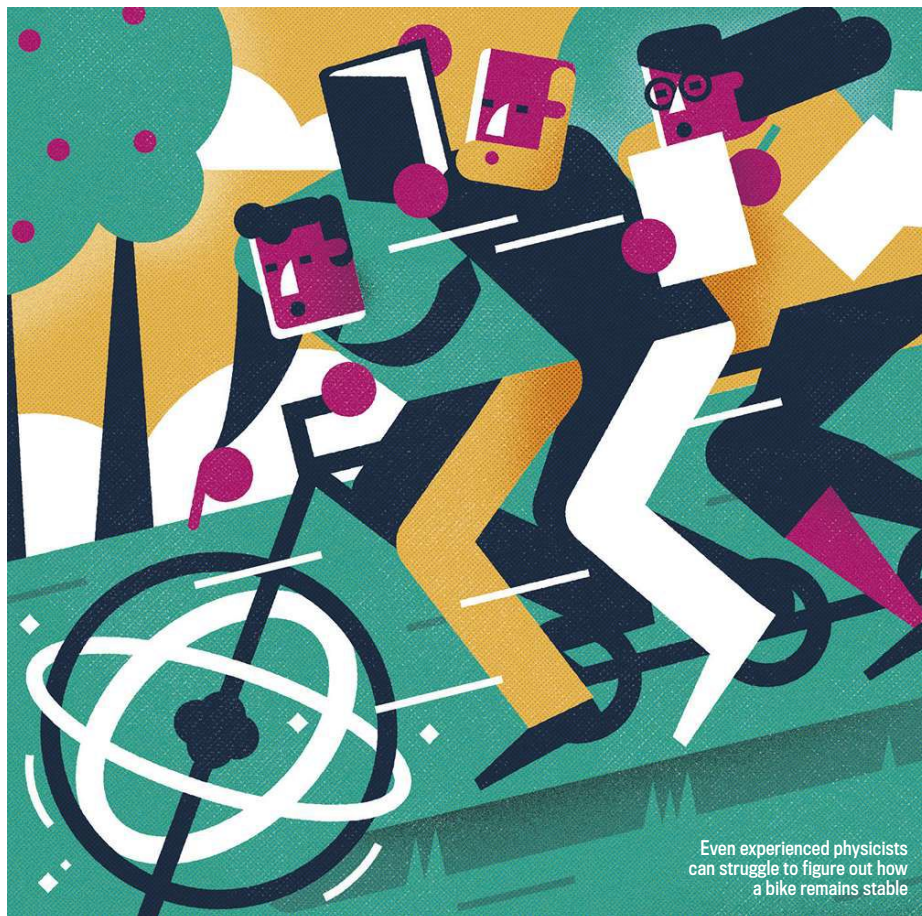
The professor hailed the strange powers of gyroscopes, and his audience applauded. But then it all got nasty. Despite his international reputation – he helped pioneer maglev propulsion for trains – Laithwaite found himself shunned by the academic establishment. He was accused of the sin of venturing outside his own field and claiming he knew better than experts in theoretical mechanics. Worse, he'd declared he'd spotted something of huge importance they'd all missed, and that one day it would spark a revolution.

Then it emerged that Laithwaite was plain wrong. Gyroscopes don't violate Newton's laws of motion – as he himself admitted 20 years later (ironically, as part of a BBC documentary about scientific heretics).

But it was far too late. When he died in 1997, his ill-judged foray into science popularisation had overshadowed his entire career. Even the RI refused to publish the transcripts of his Christmas Lectures – allegedly the first and only time that sanction has been used.

Happily, the RI has now seen fit to put the offending lectures online. Anyone who watches the fourth in the series cannot help but be astounded by what gyroscopes can do.

While Laithwaite may have been wrong about gyroscopes, they do demonstrate a truth that can't be repeated often enough: that even school-level laws of physics can throw up extraordinary phenomena. Perhaps



Even experienced physicists can struggle to figure out how a bike remains stable

“When Laithwaite died, his ill-judged foray into science popularisation had overshadowed his entire career”

the most famous example is flight. Clearly, heavier-than-air planes do fly, and do so in accordance with the laws of physics. The relevant ones are summed up in the so-called Navier-Stokes equations. The trouble is that – contrary to what many textbooks claim – there's no simple explanation for what these hideously complex formulas say about how planes fly.

I recently came across a more familiar example of this phenomenon: the stability of bicycles. Many people think bikes owe their stability to the gyroscopic effect of the wheels. Yet theory and experiment show that's a minor influence. More important is the so-called 'trail effect', generated by the front forks pointing ahead of where the wheel touches the ground.

Yet a team at the Delft University of Technology recently built a bike that's stable without either gyroscopic or trail effects. It works, but no-one can explain why except via some very complex mathematics.

It has been said that no-one understands quantum theory. Therefore,

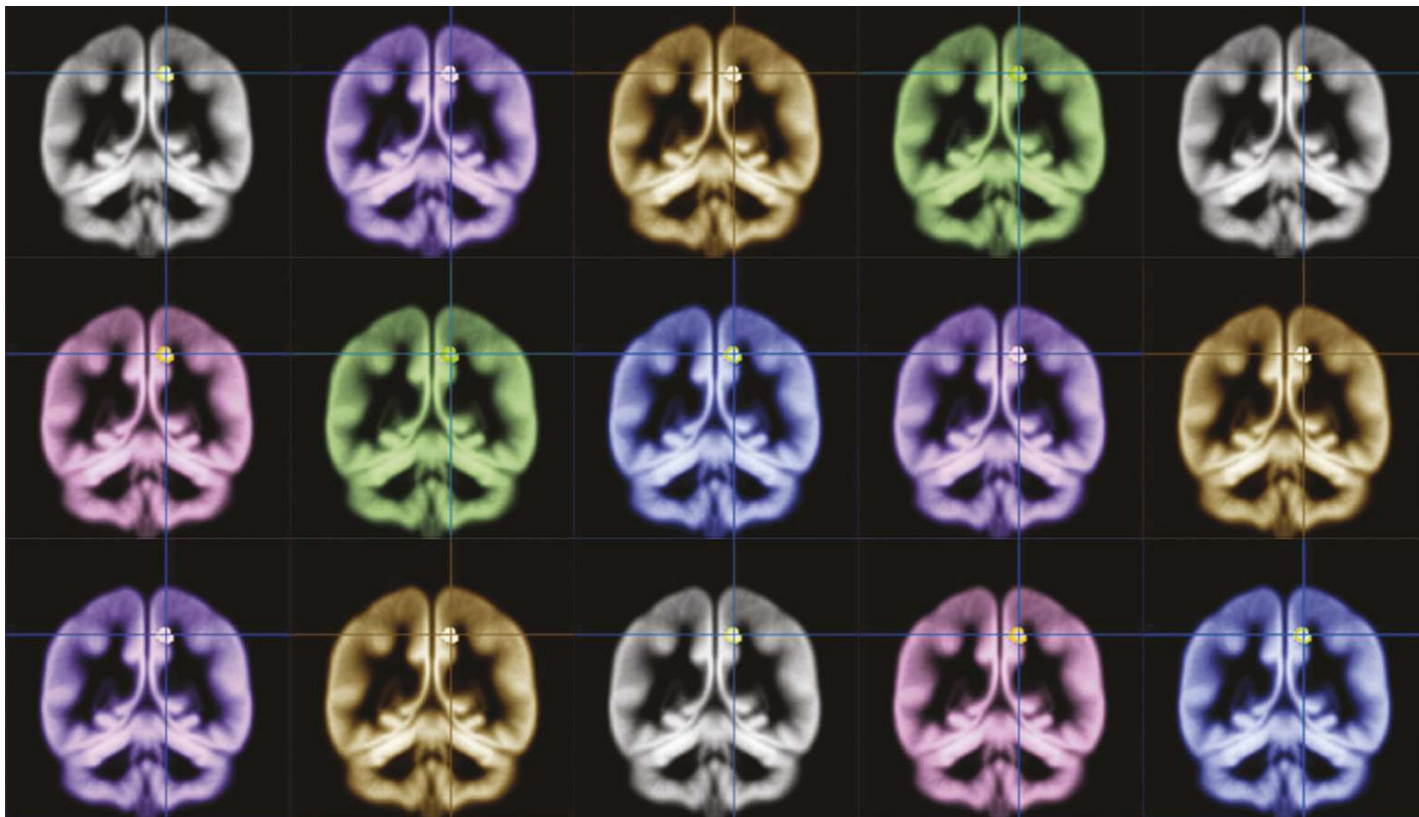
Laithwaite's notorious Christmas lectures should be celebrated for showing that even 'everyday' phenomena can defy simple explanation too. ■

ROBERT MATTHEWS is Visiting Professor in Science at Aston University, Birmingham

NEUROSCIENCE

Root of happiness found in brain

MRI scans of the brain have helped scientists find the source of happiness



IF YOU HAVE a tendency to look on the bright side of life, chances are you've got a pretty active precuneus.

A team at Kyoto University scanned the brains of volunteers using MRI and then asked them a series of questions such as how happy they are generally, how

intensely they feel emotions, and how satisfied they are with their lives.

It turned out that those who scored higher on the happiness survey had more grey matter mass in their precuneus, an area of the brain situated between the two hemispheres.

"Over history, many eminent scholars like Aristotle have contemplated what happiness is," said lead author Wataru Sato. "I'm very happy that we now know more about what it means to be happy."

Now, Sato is looking into whether or not we can train

ourselves to be happy. "Several studies have shown that meditation increases grey matter mass in the precuneus. This new insight on where happiness happens in the brain will be useful for developing happiness programs based on scientific research," said Sato.

SPACE

First photo of a planet in the making

IT'S LIKE AN ultrasound scan for a nascent planet: researchers at the University of Arizona have captured the first ever photo of a planet as it is forming.

The team noticed the nascent planet when observing LkCa15, a young star surrounded by a 'protoplanetary disk' located 450 light-years from Earth.

Protoplanetary disks form around young stars using the debris left over from the star's

formation. It is suspected that planets then form inside the disk as the dust groups together.

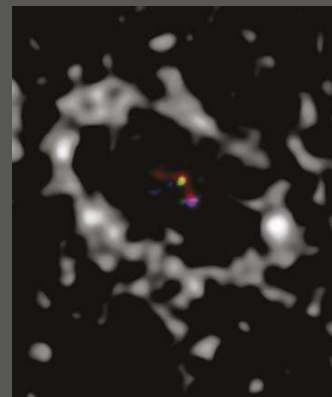
"This is the first time that we've imaged a planet that we can say is still forming," said researcher Steph Sallum.

Of the roughly 2,000 exoplanets – planets that orbit stars other than the Sun – observed so far, only around 10 have been imaged.

The photo of the planet was taken using infrared imaging

technology on Arizona's Large Binocular Telescope (LBT) and then confirmed with observations from the Magellan Telescope located in Chile.

"Results like this have only been made possible with the application of a lot of very advanced new technology to the business of imaging the stars, and it's really great to see them yielding such impressive results," said co-author Prof Peter Tuthill.



The baby planet is about 450 light-years away



HELEN CZERSKI

WHERE ARE THE GREEN MAMMALS?

The answer's simple, really, it's all in the eyes...

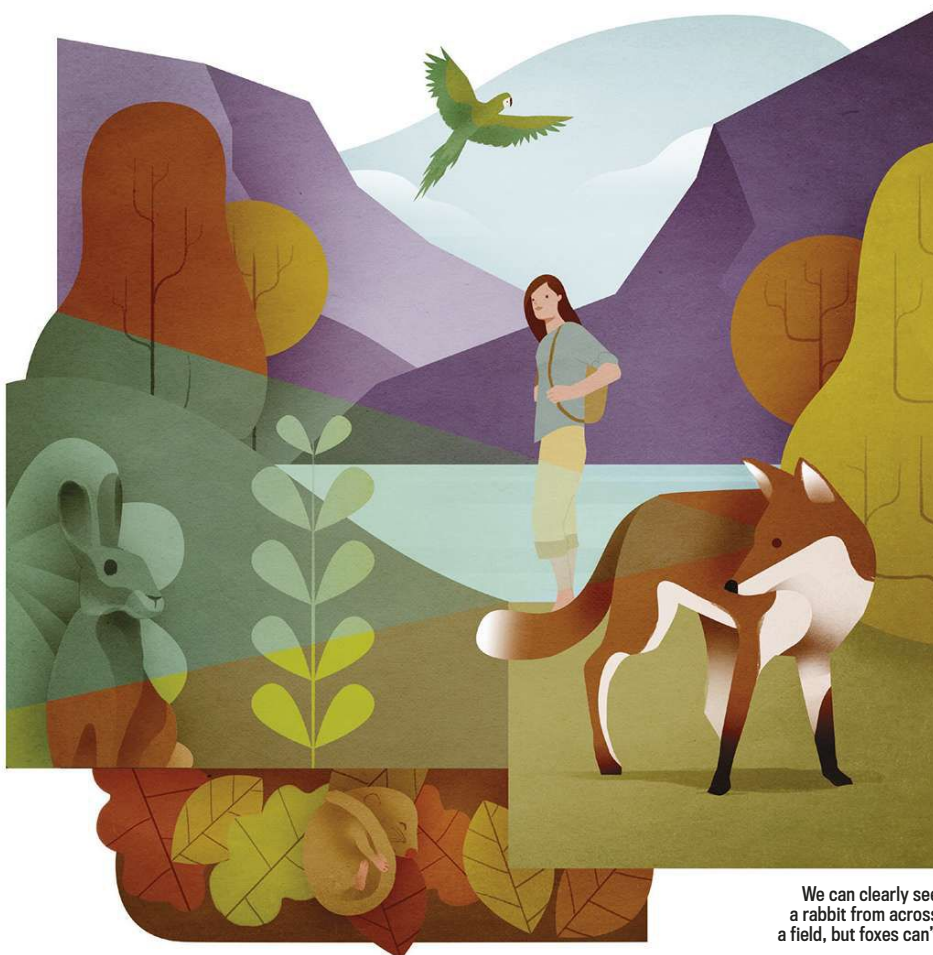
QUESTIONS ABOUT THE world often come in one of two flavours. First of all, we ask why things are the way they are (as many harassed parents will know). Why do chickens lay eggs? Why is it dark at night? Why is the world like this? But often my favourites are the second type: why *isn't* the world like this? Why don't pigs fly? Why haven't the aliens come to visit? These questions take a bit more imagination, the mental invention of how the world might be, instead of acceptance of how it is. I was asked a fantastic question of the second type recently, and I love it because it's such an obvious idea once you've thought of it, one that's staring us all in the face. But I've never heard anyone ask it before. It was: "Why are there no green mammals?"

At first glance, having a few green mammals around sounds reasonable. Small mammals like rabbits and voles spend their time surrounded by green plants, and there are plenty of predators out to get them. If they were green, they'd just blend into the background. But they're mostly brown, and I can see a brown rabbit from the other side of a field. Also, other green animals do exist: parrots and frogs and lizards. So where are the green rabbits?

The first part of the answer is that the predators like foxes and stoats don't see the world the way that we do. All mammals (apart from a handful of primates, including us) are red-green colour blind. We humans have three types of colour sensor in our eyes – red, green and blue. But we're unusual among the mammals. Like almost all the others, foxes only have two types of colour sensor, the blue and green ones. That means that they can't distinguish easily between brown and green. As far as the fox is concerned, the brown rabbit is just a darker shade of green.

But some mammals live in parts of the world where their main predators are snakes, and snakes have colour vision like ours. So predator vision can't be the whole answer.

The second part of the puzzle seems to be that it's pretty difficult for a mammal to make itself green. Plants have chlorophyll, but mammals lack the machinery to make that sort of pigment for themselves. The parrots and lizards don't have it either. They use a sneaky combination of blue and



We can clearly see a rabbit from across a field, but foxes can't

"When Kermit the Frog said, 'it's not easy being green,' I wonder whether the writers had any idea how true that was!"

yellow. The blue colour comes from the structure of the skin or feathers – they contain tiny layers that select only the blue light to be reflected back to the outside world. And the animals add to that a yellow pigment so that they look green. It's clever, but hard to copy if you have fur rather than feathers or scales. When Kermit the Frog said, "it's not easy being green," I wonder whether the writers had any idea how true that was!

The only mammal that has come close to turning itself green is the sloth, which is a creature with such a leisurely attitude to life that it rarely moves at all. The animal manages a greenish tinge because its long fur is home to a garden of sloth-specific green algae, with some moths and beetles and fungi thrown in to boot. The sloth is blending into the forest by turning itself into a smaller forest.

So, there are no true green mammals. But it's a funny thought that

a dormouse with pale brown fur probably thinks that it is the same colour as the grass in which it's hiding. So perhaps being green just depends on your perspective. ■

DR HELEN CZERSKI is a physicist and BBC presenter whose most recent series was *Colour: The Spectrum Of Science*

NANOTECHNOLOGY

'Nano-subs' may soon be swimming in your bloodstream

REMEMBER THE MINI submarine Dennis Quaid used to cruise around the human circulatory system in classic 80s sci-fi movie *Innerspace*? Well, researchers at Rice University have made the next best thing: a 244-atom nano-submarine that could be used to deliver medicines inside the body.

The subs are powered by motors that operate in a similar fashion to a bacteria's flagellum – the tail-like filament that allows microbes to swim through fluids.

When excited by ultraviolet light, the bond that holds the rotor to the body changes state allowing it to rotate a quarter turn. Then as it returns to its resting state, it jumps again rotating another quarter turn. This process continues so long as the light is on.

The motors run at more than 1,000,000rpm and can reach

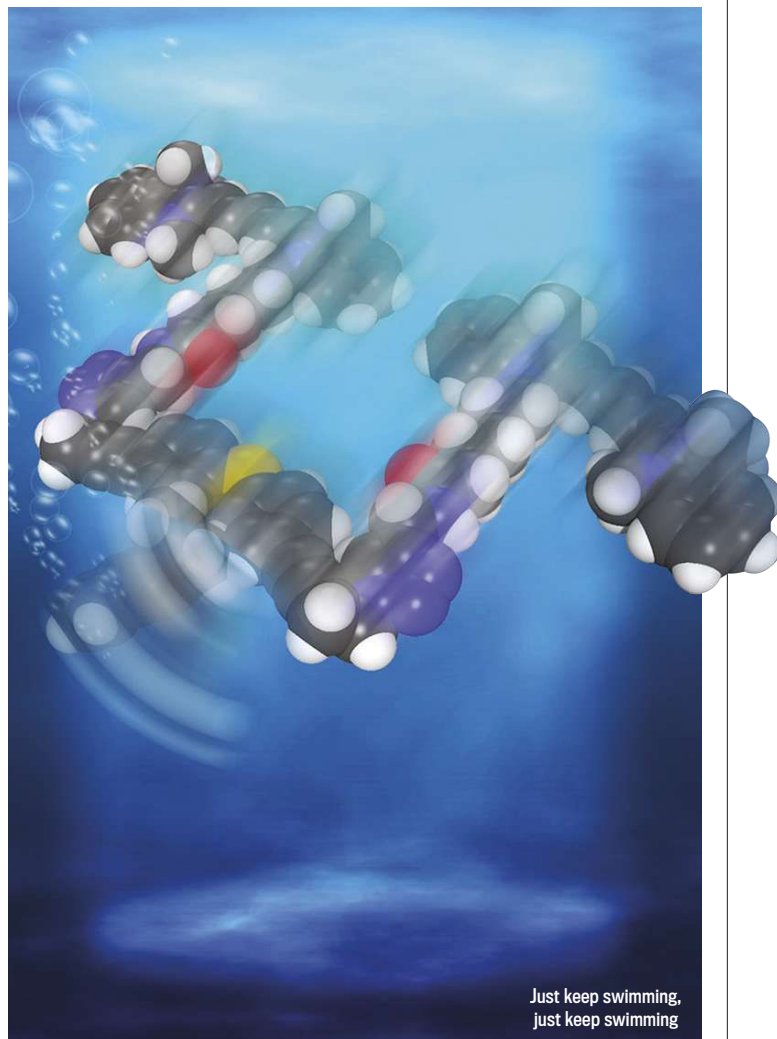
speeds of just under 2.5cm per second. This may not sound particularly nippy, but in molecular terms it's breakneck speed.

The subs can't be steered yet, but the study proves the molecular motors are powerful enough to drive subs through solutions of moving molecules of about the same size.

"This is akin to a person walking across a basketball court with 1,000 people throwing basketballs at him," said lead researcher James Tour.

With further refinement, the researchers hope the nanosubs will be able to carry cargoes for medical and other purposes.

"There's a path forward," co-author Víctor García-López explained. "This is the first step, and we've proven the concept. Now we need to explore opportunities and potential applications."



Just keep swimming, just keep swimming



PATENTLY OBVIOUS with James Lloyd

Inventions and discoveries that will change the world

Tech for tots

YOU MIGHT NOT think that all that cooing baby talk has much of an effect, but studies show that speaking to your infant has a crucial impact on their development. The Starling is a star-shaped device that clips to your baby's clothes and keeps track of the number of words you speak to them, lighting up green when you've reached your daily target. The companion app will even suggest activities if you're at a loss for words.

Patent pending



Raising the bra

WHAT DO GECKOS and women's underwear have in common? A lot more than you might think. Geckos can run across ceilings thanks to the microscopic structure of the their toes. Now, US engineer Anthony Roy has created a silicone-based material called GeckTeck that uses the same principle to attach a strapless bra to the skin, providing a comfortable adhesive that can be reused thousands of time.

When fixed to the band of a bra, it allows the wearer to glam up without having to spend the whole night fiddling with their outfit. Now, where's that strapless crop top?

Patent pending

Dunk-proof phones

WHEN THE BEST way of saving a wet phone involves plunging it in a bowl of rice, you know that it's time for change. Apple is patenting a system that detects water inside your phone and squirts it out of the speakers. The technology works by varying the electrical charge of electrodes inside the speaker cavity – this alters their water-repelling properties and moves the liquid towards the exit. Maybe the technology will find its way into the iPhone 7, in which case we'll be able to save the rice for that tikka masala.

Patent application number: US 20150326959



STEPHEN BAXTER

THE FIRST MARTIAN

Will we be able to reproduce in space?

AT CHRISTMAS WE commemorate the birth of Jesus. The Bible shows Jesus's birth as laden with significance, with the mysterious star hanging in the sky over Bethlehem, and the visit of three sages from the east. It seems likely, though, that nobody at the time realised the significance of Jesus, born as he was to an 'ordinary' family at a moment when they were displaced from their home because of the bureaucracy of the Roman Empire, a ladder of power at which Jesus's family was somewhere near the bottom.

It is thought there have been one hundred billion human births over the course of history, and few have been seen as notable at the time. This is particularly true in an age in which inherited power is a less significant factor in our society. We do know that because of his ancestry, Prince George will be king some day, but such figures are the exception now.

But there are occasions when a birth of an otherwise 'ordinary' person can be seen to be significant. I playfully noted in my contribution to a recent feature on a possible Moon base (November, p67) that the birth of the first human child born on the Moon will surely be a globally celebrated event – that is, if it happens at all.

The capability of the human reproductive systems to adapt to conditions on the Moon or Mars, or indeed in the microgravity of an orbiting station or a spacecraft, is in fact an open question. NASA and other agencies have been funding studies into aspects of the problem, on the International Space Station and elsewhere. In 2014 Dr Joseph Tash, a NASA researcher at the University of Kansas, reported on such experiments, which showed that the deformation of male rats' testes in low gravity seemed to reduce their functionality in producing sperm, while the ovaries of female mice were shrunk. Even after fertilisation, experiments have shown that reduced gravity harms the development of mouse embryos.

So far, of course, the issue of space births hasn't arisen. At present NASA offers its astronauts the chance to freeze sperm or eggs before spaceflight. And it has no official policy on sex in space, other than a request issued for astronauts to abide by a 'Code of Professional Responsibility' that commits them to 'honourable behaviour'. But with the



The first lunar baby will pave the way for births on Mars and other planets

“Let's hope that when it comes, the first birth in space will be a cause, not for recrimination, but for celebration”

prospect of long-duration deep space missions on the horizon, let alone long stays on bases on the Moon or Mars – and human nature being what it is – it would seem prudent to prepare for the issue to arise.

In a way, the first space birth will have precedents. After humans spread out of Africa, some 60,000 years ago, there must have been a first human birth in Australia, and 10,000 to 15,000 years ago a first in the Americas. These were continents where no hominid had walked before, but there was no media around to witness such landmarks.

Let's hope that when it comes, the first birth in space will be a cause, not for recrimination, but for celebration. Arthur C Clarke foresaw this decades ago in a charming short story called *Out Of The Cradle, Endlessly Orbiting* (1959) about the first lunar birth: "That was the moment, gentlemen, when I knew that Man had really conquered space." Or, to be more precise, Woman. Later will come the first Martian, the first on Europa and Titan – and, ultimately, the first baby born under another star, the lantern of Bethlehem or not. ■

STEPHEN BAXTER is a science fiction writer who has written over 40 books. His latest is *Xeelee: Endurance*

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SCIENCE AND TECHNOLOGY

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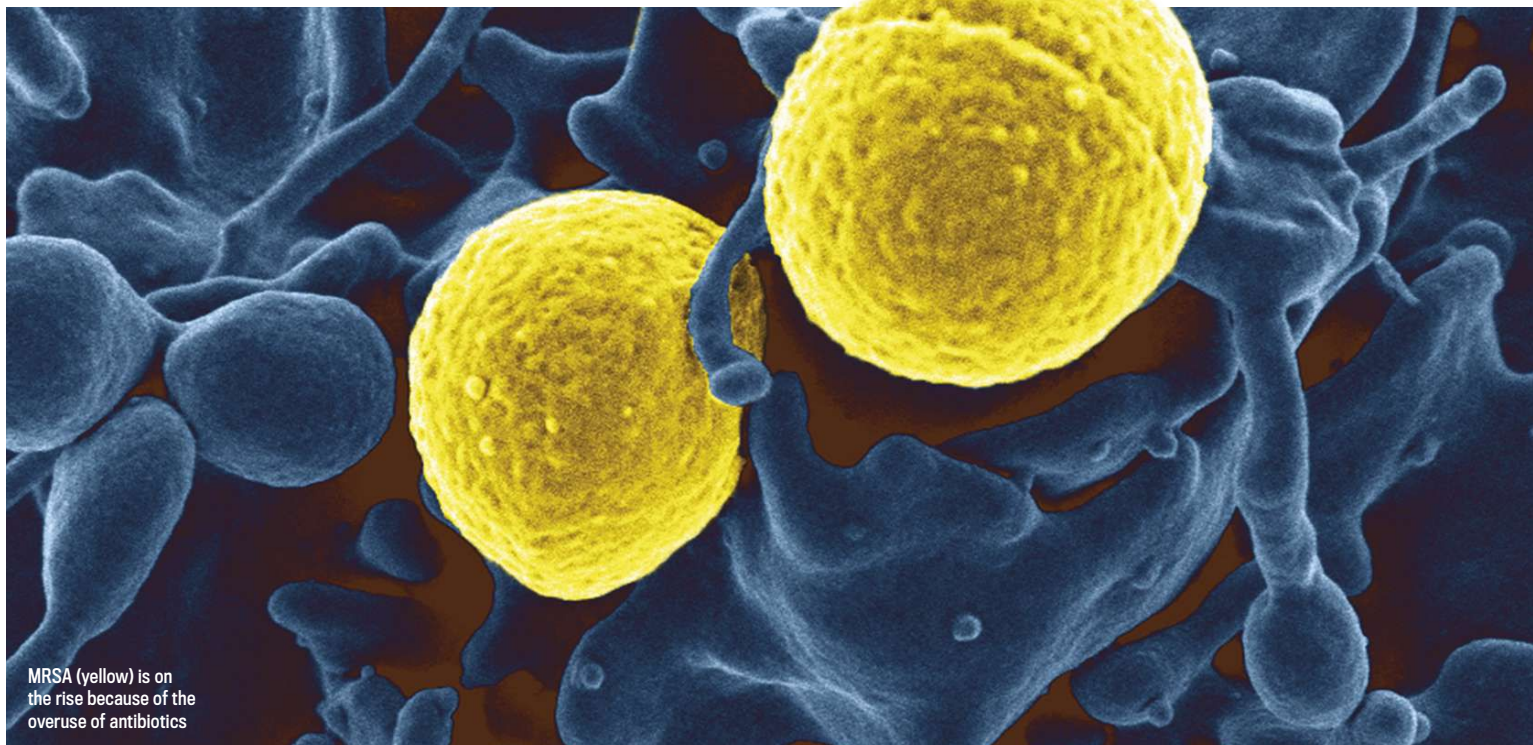
FOCUS

SCIENCE AND TECHNOLOGY

2015: THE BEST EVER YEAR FOR SCIENCE?

The past 12 months have been incredible for science. We've explored Pluto, revolutionised medicine, found evidence of water on Mars and brought animals back from the brink of extinction. So will 2015 go down in the history books as a turning point? **Brian Clegg** looks back over some of the year's most impressive scientific achievements





MRSA (yellow) is on the rise because of the overuse of antibiotics

NEW ANTIBIOTIC IS DISCOVERED

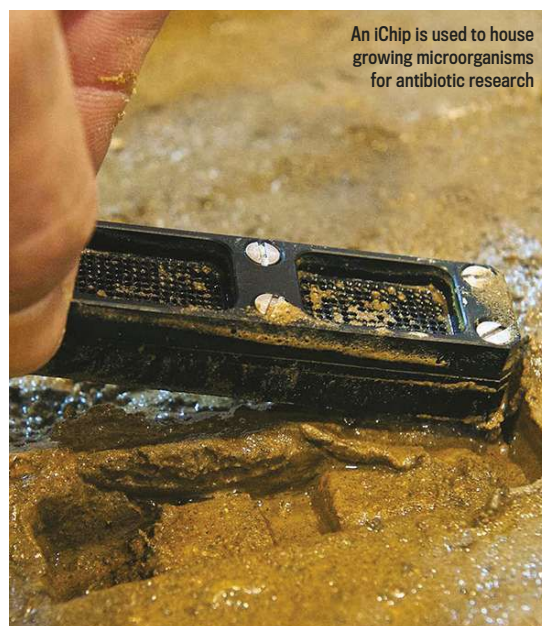
AS BACTERIA INCREASINGLY evolve to survive the attack of antibiotics, we could see modern medicine devastated. Overuse of antibiotics means that we are threatened by 'superbugs' like MRSA that can survive our armoury.

Until 2015, we hadn't developed a new antibiotic for decades. But two new substances are under test that could extend the fight against superbugs. One, being developed by drug company Novartis, is a variant of the existing isoniazid antibiotic that is used to target antibiotic-resistant tuberculosis. It works because it bypasses the mechanism used by a bacterium to develop resistance. But more dramatic is teixobactin, which was derived from 'wild' bacteria in soil

and works in a different way to conventional antibiotics, attacking a part of the bacterial cell that is less able to mutate and produce resistance. "Uncultured bacteria make up approximately 99 per cent of all species in external environments, and are an untapped source of new antibiotics," said the researchers. If a drug is developed from teixobactin, it could be effective against bacteria like MRSA for decades to come.

WHY SHOULD I CARE? An increase in antibiotic resistance in bacteria is putting our lives at risk.

WHAT'S NEXT? Researchers are hunting for more antibiotics like teixobactin in the wild.



An iChip is used to house growing microorganisms for antibiotic research

PHOTO: GETTY, NASA, TODD MARSHALL, ILLUSTRATOR: ANDY POTTS

THE YEAR IN BRIEF...

JAN

BIG FISH

In January, a fossil that had been sitting in a Glasgow museum since 1959 was identified as a previously unknown species of ichthyosaur, *Dearcmhara shawcrossi*. The marine reptile lived in Scottish waters 170 million years ago, and grew up to 4m long.



A NEW EARTH?

Exoplanet Kepler 438b was confirmed in January, and is thought to be the most Earth-like exoplanet yet discovered. Sadly, further studies have shown that it's too close to its parent star to ever be capable of hosting carbon-based life, due to high radiation levels.



LIGHT PHOTOGRAPHED AS A PARTICLE AND WAVE

A WEIRD ASPECT of quantum theory is that a quantum object – like a photon of light – can either act as a particle, or as a wave. The assumption has always been that if we make full measurements of a quantum object that support it being a wave, then it can't simultaneously appear as a particle. This is called the 'principle of complementarity'. However, researchers at the École Polytechnique Fédérale de Lausanne published an image they described as: "A photograph of light as both a particle and a wave."

The experiment produced standing waves in a wire that simultaneously interacted as particles with a stream of electrons. This is an impressive experiment, though it doesn't break the principle of complementarity, as the waves in the wire weren't light, but special vibrations called plasmons. In the future this technique could be used to get information into and out of quantum computers.

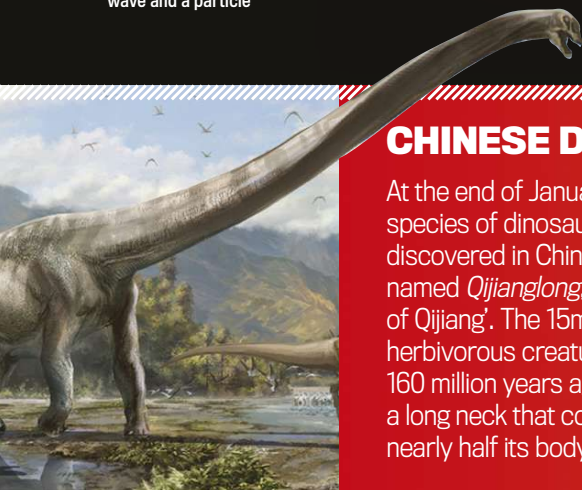
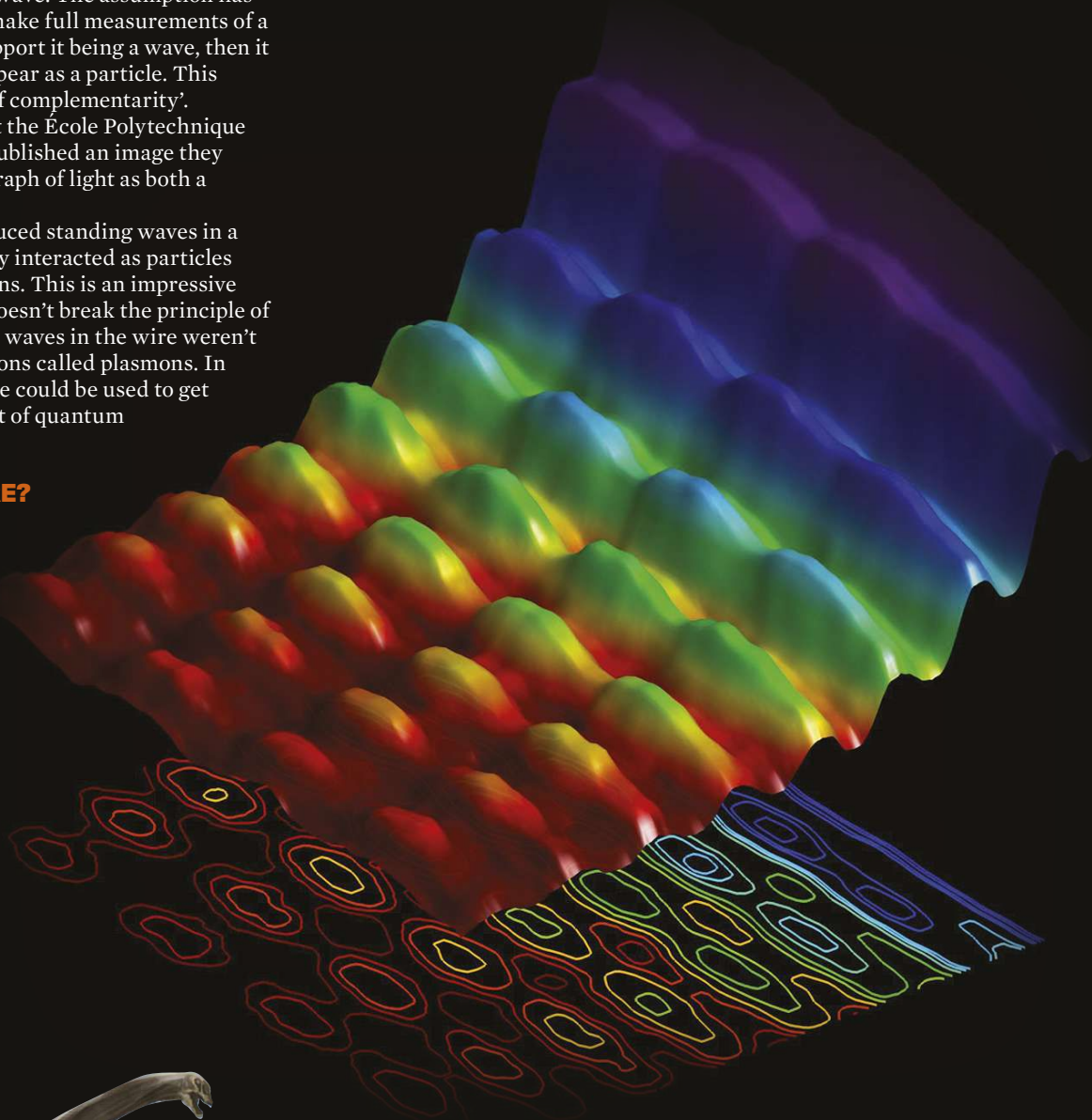
WHY SHOULD I CARE?

An enhanced understanding of how photons work could lead to the development of powerful quantum computers.

WHAT'S NEXT?

A lot more work is needed before practical applications can be developed.

The first photograph of light behaving as a wave and a particle



CHINESE DRAGON

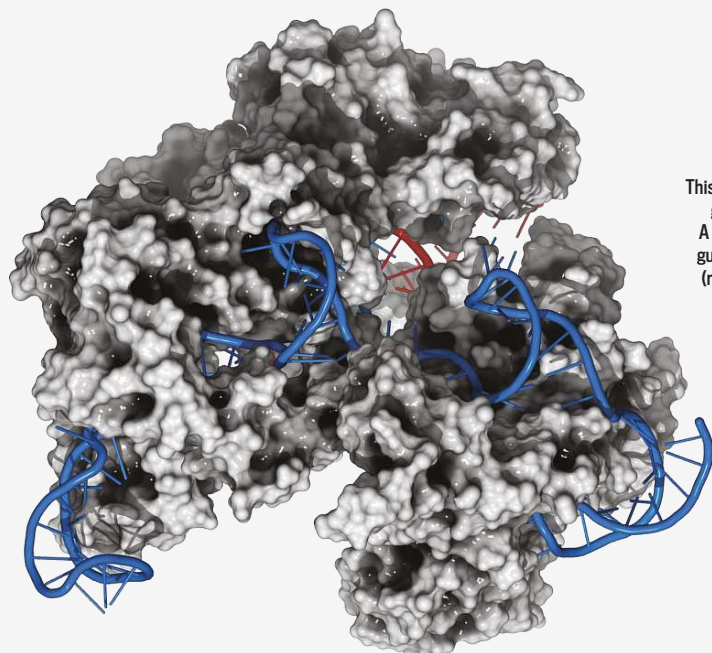
At the end of January, a new species of dinosaur was discovered in China, and named *Qijianglong*, 'the dragon of Qijiang'. The 15m-long herbivorous creature lived 160 million years ago, and had a long neck that comprised nearly half its body length.

MAR



A NEW DAWN

On 6 March, NASA's Dawn spacecraft went into orbit around Ceres, becoming the first craft to visit a dwarf planet. At time of writing it is still mapping the planet's surface from low orbit, and will continue to send back data for many months to come.



This is the CRISPR-Cas9 gene-editing system. A protein (grey) uses a guide (blue) to cut DNA (red) in the right spots

THEY DID WHAT?

A number of scientists took more unorthodox routes in their research in 2015...

APES WATCHED 'HORROR FILMS'

Kyoto University researchers showed two movies to apes. In the first, a person dressed as an ape leaps out from one of two doors. In the second, a person picks up a hammer and bashes the 'ape'. They used eye-tracking to see what was holding the apes' attention, then played the films again 24 hours later. When watching the first video for a second time, the apes watched the door from which they'd seen the 'ape' jump out. With the second video they stared at the hammer. This proved that apes can store and retrieve information in their long-term memories.



MUSIC COMPOSED FOR CATS



David Teie, a University of Maryland composer, wrote music specifically for cats. Cats approached and rubbed themselves on the speakers much more when they heard the feline compositions than when they were played classical music. The team says that species-specific music could be used to calm animals being kept in zoos or animal shelters.

CHEMISTS UNBOILED AN EGG

A team from the University of California figured out a way of untangling proteins in cooked egg whites and allowing them to refold, as if the egg had been 'unboiled'. First, they hard boiled the eggs. They then liquefied the cooked egg white with urea, before using a 'vortex fluid device' to apply forces to the tiny strands of protein in the white. This separated the proteins back to their clear form. Being able to reform proteins from yeast or *E. coli* bacteria may lead to better methods for making proteins, which could help create cheaper cancer treatments.



HUMAN DNA EDITED SUCCESSFULLY

THE REMARKABLE GENETIC tool CRISPR (standing for Clustered Regularly Interspaced Short Palindromic Repeat) was developed in 2012. It transformed DNA editing from an expensive, slow process to a rapid, cheap technique. The approach, which employs a mechanism found in the immune system to target specific genes, was used this year for the first time to make modifications to human embryos by scientists at China's Guangdong Province Key Laboratory of Reproductive Medicine and Sun Yat-sen University, Guangzhou.

The team was attempting to modify the gene HBB that mutates to cause the blood disease beta-thalassaemia. Although the team was working on embryos with an extra set of chromosomes, meaning that the embryos cannot develop to birth, there were concerns about the ethics of the process if it were ever to be used on viable embryos, as any changes could be passed on to offspring with uncertain results. Also, the experiment did not produce

a successful modification in the majority of the 86 embryos tested. Project leader Junjiu Huang said: "If you want to do it in normal embryos, you need to be close to 100 per cent. That's why we stopped."

Even where the modification worked, there were extra mutations where the CRISPR mechanism made changes to other genes – far more unwanted modification than had occurred in other experiments on mice and adult human cells. This highlights the significant obstacles that stand in the way of using gene editing to eliminate genetic disorders, yet the technique still holds out hope for cures in the future.

WHY SHOULD I CARE? This piece of Chinese research opens up the prospect of 'designer babies' – for good or ill.

WHAT'S NEXT? More research and hopefully some kind of international accord on the ethics involved in the editing of genes.

SOLE POWER

A team in Canada developed a new material that could make tumbles in winter a thing of the past. The material consists of rubber that's packed with tiny glass fibres. On dry surfaces it acts like normal rubber, but in icy conditions it offers greatly improved grip.



APR



NOT SO DARK

A Durham University team suggested that dark matter may not be so dark after all. They believe they found evidence of dark matter trailing behind its associated galaxy – suggesting the mysterious stuff is interacting with something other than just gravity.

PHILAE WAKES UP

LANDING THE PHILAE probe on Comet 67P/Churyumov-Gerasimenko was one of the biggest stories of 2014, with drama erupting as the probe's anchoring harpoon failed to attach, putting it in a slow motion bounce across the surface that left its solar cells shaded from the sunlight. For 60 hours, Philae was active, its 10 instruments sensing and drilling the surface of the comet, but then the probe ran out of power. As 67P continued in its orbit, chunks of the comet's surface were melted by the Sun, letting light reach the lander once more. And on 14 June, Philae's Twitter account carried the message "Hello Earth! Can you hear me?" Rosetta had detected a weak signal from its lander.

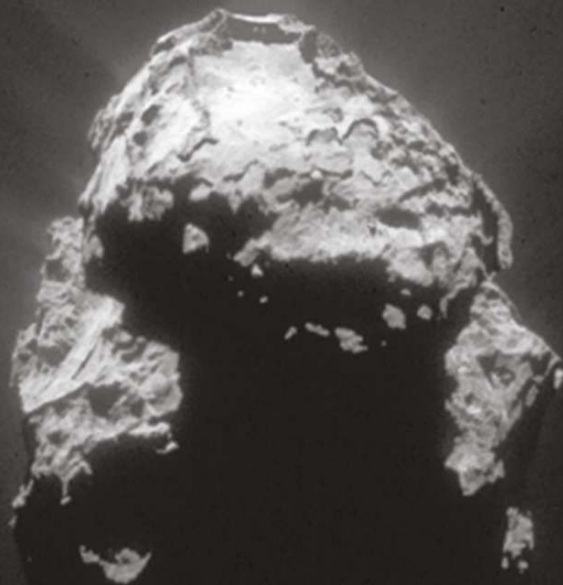
The initial link lasted for just two minutes, but was enough to establish that the systems had survived. At the time, the comet was around 215,000,000km from the Sun and 305,000,000km from the Earth, travelling at around 31km/s. Since then, another five contacts have been made with Philae, with the longest lasting around 18 minutes. The information from Philae has been sparse, but has at least enabled a study of the changes in surface temperature. Most surprising of all, analysis of the data revealed that there was oxygen present on the comet in small amounts. After July, Rosetta had moved too far from the comet to have any contact with Philae, though the orbiter has continued to provide information about 67P and may have had one more chance to receive data from the surface around the end of the year.

As for the lander, to quote members of the team, "If you, too, are wondering: will we hear from Philae again? Guess you will just have to wait and see."

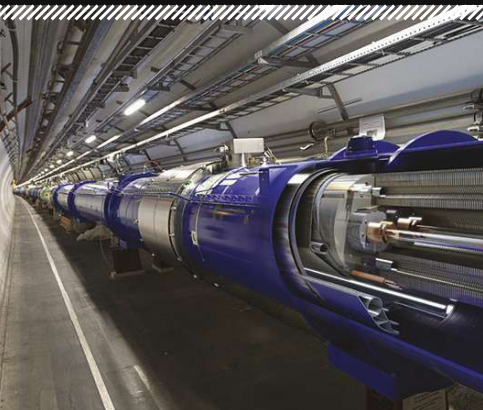
WHY SHOULD I CARE? Because even if you have no interest in astronomy, landing on an object whizzing through space at a top speed of 135,000km/h is mightily impressive.

WHAT'S NEXT? NASA scientists will be analysing data sent back by Philae for several years yet – new revelations may well await.

PHOTO: NASA/JPL-CALTECH X3, FWS/US FISHERIES, KRIS KRUG/FICKR, ANDY ZHANG, CERN



The Rosetta mission increased our knowledge of Comet 67P/Churyumov-Gerasimenko



JUN BACK IN THE GAME

The Large Hadron Collider was switched back on after a two-year break. During that time, the particle accelerator underwent a major upgrade, doubling the energy of its beams so that it can now collide particles at higher energies.



PAIN-FREE JABS

Students at Rice University, USA developed a new way of giving injections. The device is placed against the skin for 60 seconds while an endothermic (heat-absorbing) reaction occurs inside it, numbing the area so a jab can be given painlessly.

PLUTO'S LANDSCAPE REVEALED

WHEN THE NEW Horizons probe launched in January 2006, it received little media coverage. Yet in 2015, after travelling nearly five billion kilometres, this 478kg spacecraft, around the size of a piano, captured everyone's imagination with its stunning images of Pluto. After picking up speed with a slingshot manoeuvre around Jupiter in early 2007, the probe hurtled towards the outer reaches of the Solar System at speeds that peaked at 80,000km/h, yet it took another seven years to reach its destination.

In January, New Horizons sent back the first photographs of Pluto and its main moon Charon, showing them as fuzzy dots. By May, features were beginning to appear in the images, along with Pluto's smaller moons, Nix, Hydra, Styx and Kerberos.

On 14 July the probe made its closest flyby, around 12,500km above Pluto's surface, providing remarkably detailed images of the dwarf planet's topography. Among the discoveries was a large,

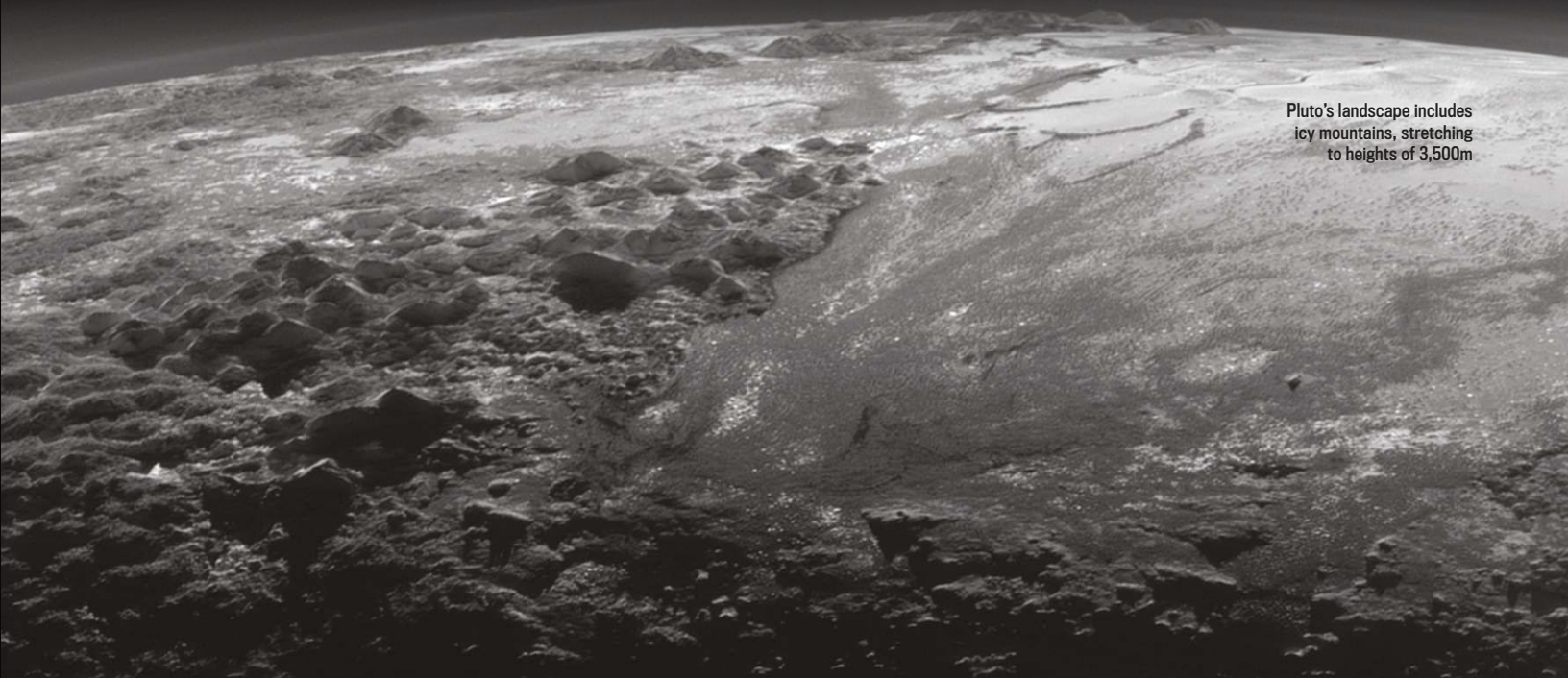
heart-shaped feature measuring around 1,600km across. New Horizons Principal Investigator Alan Stern commented: "My prediction was that we would find something wonderful, and we did." Despite the complexity of its journey, the probe was just one minute behind its ETA. In October, New Horizons used a 25-minute blast of its thrusters to change course, heading another 1.6 billion kilometres out towards an object called MU69, in the distant part of this region of the Solar System known as the Kuiper Belt.

WHY SHOULD I CARE? Because our knowledge of our own Solar System is still far from complete, and this is a significant new piece in the puzzle.

WHAT'S NEXT? Now that New Horizons has 'done' Pluto, it's moving on to the Kuiper Belt, and should arrive there in 2019.



Pluto looked completely different to how it had previously been visualised



Pluto's landscape includes icy mountains, stretching to heights of 3,500m



DINO CRAZY

The arrival in cinemas of *Jurassic World* in June saw the world go briefly dinosaur-mad. The result was a short-lived publicity boom for the likes of Dr Beth Shapiro at University of California Santa Cruz and others looking the possibility of reviving long-extinct species.



BYE BYE, BIG CAT

On 16 June, the US Fish and Wildlife Service declared the eastern cougar (*Puma concolor cougar*) extinct. But don't be too upset: there hadn't been a confirmed sighting since the 1930s, and not all zoologists acknowledged the subspecies in any case.

BLACK-FOOTED FERRET SAVED FROM EXTINCTION BY FROZEN SPERM

THERE IS MUCH talk of reviving extinct animals such as mammoths from frozen DNA. While this is still some way from being possible, 2015 saw an endangered species put on the road to recovery using decades-old frozen sperm.

The black-footed ferret, a North American mammal, was already in severe danger of extinction when 18 of them were put in a captive breeding programme back in the 1980s. The sperm of six ferrets, including that of one called 'Scarface', was frozen. Then in August this year, Scarface became a donor father, even though he died around 20 years ago. The frozen sperm was successfully used by American zoos and the Smithsonian Institute to

artificially inseminate living females, therefore improving the species' chance of survival by boosting genetic diversity in the tiny population. By adding fresh genes, the risk from inbreeding has been reduced.

The current breeding programme has helped the ferrets reach a population of around 300.

WHY SHOULD I CARE? The technique pioneered in black-footed ferrets could be used to help save other endangered species.

WHAT'S NEXT? A more concerted global effort to build biobanks of animal sperm and eggs looks increasingly like the smart move.

QUANTUM TELEPORTATION RECORD SMASHED

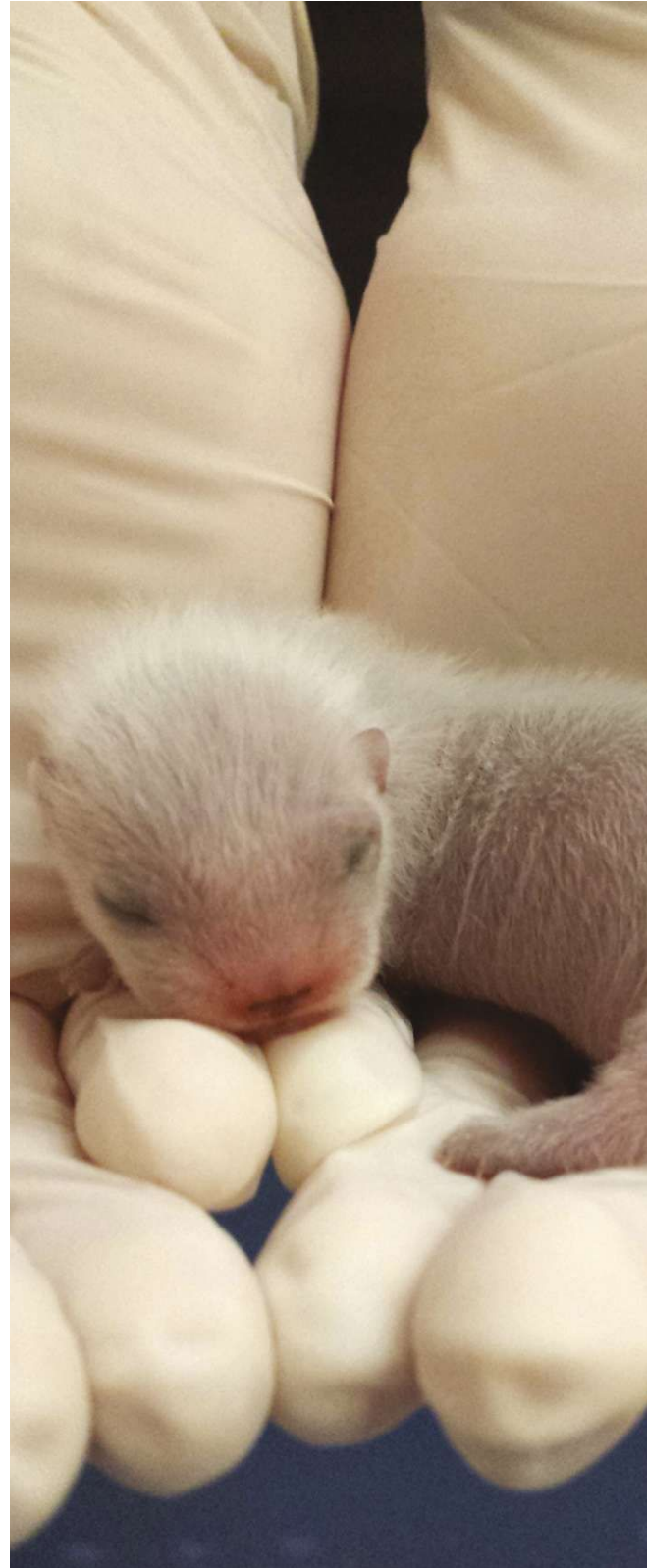
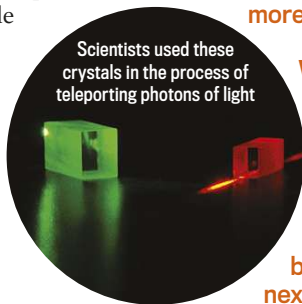
QUANTUM ENTANGLEMENT took a big step forward this year. In this small-scale version of a *Star Trek* transporter, properties of a quantum particle are transferred to another remote particle. The remote particle becomes indistinguishable from the original. This is only possible using a mix of the spooky connection of entanglement and conventional data transfer. The US researchers achieved teleportation along a 100km optical fibre link, four times the previous

record. Teleportation keeps the data intact, which is crucial for quantum computers and quantum encryption.

WHY SHOULD I CARE? It could lead to unbreakable encryption - no more hacked bank accounts!

WHAT'S NEXT? Chinese researchers are planning a long-distance communication experiment that will teleport particles between satellites in the next couple of years.

Scientists used these crystals in the process of teleporting photons of light



CANNIBAL CLUE

Papua New Guinea's Fore tribe, who ate human brains until the 1950s, have developed a natural resistance to kuru, a form of encephalopathy. Understanding how this new-found immunity developed could lead to treatments for CJD, Alzheimer's and Parkinson's disease.

JUL



TINY EYES

Warnowiids are tiny, single-celled marine creatures - yet in July it was discovered that their bodies contain a structure that's remarkably similar to the human eye. It demonstrates that natural selection can reach a single design through different evolutionary paths.

Frozen sperm has helped secure the future of the black-footed ferret



Tissue could be replicated with 3D printing, allowing research without the need for human experiments

SCIENTISTS CREATED 3D PRINTED HUMAN TISSUE

EXPERIMENTAL 3D PRINTING of human tissue has been underway for some years, but 2015 saw real breakthroughs. A team from the University of California, San Francisco used a revolutionary technique called DNA Programmed Assembly of Cells to produce tiny models of living structures containing several hundred cells.

Within a decade it could be possible to build a living model of a cancer patient's affected organ, which could be used to test drugs for side effects.

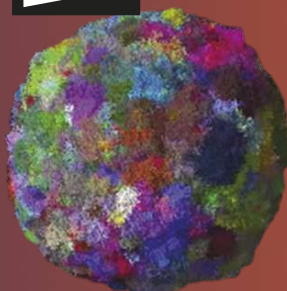
WHY SHOULD I CARE? It opens up a world of research possibilities, without the need for human experiments.

WHAT'S NEXT? Longer term, it could be possible to grow complete organs, which would slash the length of transplant waiting lists.

The new technique called DNA Programmed Assembly of Cells used tiny 'biobricks', not unlike Lego, to build human tissue



AUG



BATTLING CANCER

Scientists at Harvard, Johns Hopkins and Edinburgh produced the first 3D computer model of how tumours grow and mutate. It's hoped the model will enable more effective treatments.



ORIGINS OF LIFE

Japanese researchers modelling the effects of high-power collisions on amino acids found that such impacts could trigger the production of peptides – suggesting that a comet impact may have been the spark that ignited life.

LIQUID WATER FOUND ON MARS

IT HAS BEEN known for some time that there was water on Mars, notably in the polar ice caps. However, Mars has a combination of a very low atmospheric pressure – which means that any liquid water quickly evaporates – and an average surface temperature of around -63°C , making liquid water unlikely to form in the first place. It was, then, a major surprise when NASA announced evidence that there is flowing liquid water on the surface of the planet.

While no water was observed on the move, scientists found dark, narrow streaks a few hundred metres long, running down gulleys, which appeared to ‘ebb and flow over time’. These are likely to have been produced by flowing water, especially as hydrated salts have been discovered on those slopes. These chemical compounds containing water are likely to have formed while liquid water was present.

The deposits were discovered by the Mars Reconnaissance Orbiter. This craft uses an imaging spectrometer, which detects the presence of different chemical structures from the light reflected by them. If the compounds were dissolved in the water they would lower the freezing point, in the same way that salt does when spread on ice, enabling the water to stay liquid despite being well below 0°C . As NASA’s John Grunsfeld put it, “Our quest on Mars has been to ‘follow the water’ in our search for life in the Universe.” This discovery will provide an important focus for future attempts to find life on Mars.

WHY SHOULD I CARE? The presence of water makes the presence of life – of some kind, at some point – a much more viable proposition.

WHAT’S NEXT? We’re getting to a point where probes and landers have told us all they can about Mars – now we need to actually go there.

PHOTO: NASA/JPL-CALTECH X3, NATIONAL GEOGRAPHIC MAGAZINE, GETTY X7, ISTOCK X2


OCT

ALONE AFTER ALL?

New research published in October suggested that while there may be millions of Earth-like planets, Earth itself is one of the oldest – and that most habitable planets have yet to be formed. So no aliens will be arriving soon...

INSIDE JOB



French football team FC Nantes revealed that it has been tracking players’ internal temperature during matches using an ingestible pill that sends data to a nearby receiver. They were researching the effects of ice therapy on recovery times.

NOV

HUMAN-LIKE SPECIES DISCOVERED

THE DISCOVERY OF a new human species is bound to make news, but it takes time to go from finding fossils to a clear scientific result. It was back in late 2013 that a team led by Lee Berger of Witwatersrand University, South Africa, followed up a sighting by cavers in a concealed chamber in the Rising Star cave system. The caves are around 29km from Johannesburg, in an area that has been given the nickname 'the cradle of humankind', as many fossils from early humans have been found there.

In total, a remarkable 1,500 fossil fragments were removed from the cave, and this year the world discovered what they found. The bones made up the partial

remains of 15 separate individuals of an early human species. *Homo naledi*, as the hominins have been called, appears to have walked upright and reached around 1.5m in height, but had hand and shoulder structures suggestive of spending considerable time in trees.

The skeletons had a mix of features, with a skull that suggested a brain around one-third the size of ours but with feet that looked surprisingly modern. The next step is to discover how old these bones are. *H. naledi* could be early humans, dating back two to three million years, or could be a relict that survived to coexist with *Homo sapiens*.

WHY SHOULD I CARE?

Because humankind's come a long way... aren't you curious to know how we got here?

WHAT'S NEXT?

The exact age of the *H. naledi* still needs to be verified, so that's the priority right now.

Could *Homo naledi* have lived alongside *Homo sapiens*?

BEST OF THE REST

2015 wasn't the only great year for science...

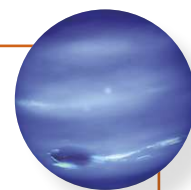
1543 The publication of Nicolaus Copernicus's (pictured) *De Revolutionibus Orbium Celestium* and Andreas Vesalius's *De Humani Corporis Fabrica*



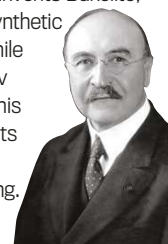
revolutionise the worlds of astronomy and medicine.

1846

US dentist William Morton pioneers the use of general anaesthetic, while in Germany, Johann Gottfried Galle and Heinrich Louis d'Arrest are the first to identify the planet Neptune.



1907 Leo Baekeland (pictured) invents Bakelite, the first synthetic plastic, while Ivan Pavlov conducts his experiments regarding conditioning.



1913 Our understanding of the elements leaps forward, thanks to Henry Moseley defining atomic numbers and Niels Bohr (pictured) coming up with a new model for atomic structure.



1917 Ernest Rutherford (pictured) splits the atom, spawning the discipline of nuclear physics. In France, US army surgeon Oswald Hope Robertson pioneers the use of blood banks.



1927 Werner Heisenberg lays the foundations for quantum mechanics with his uncertainty principle. That year, the first transatlantic telephone service is also introduced.



1953 James Watson and Francis Crick describe DNA. The Miller-Urey experiment shows how the first amino acids may have formed.



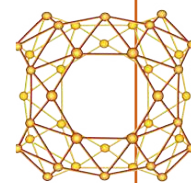
1961 Russia's Yuri Gagarin (pictured) becomes the first man in space. Back on Earth, the World Wildlife Fund is established by biologist Julian Huxley and ornithologist Peter Scott.



1967 At Cambridge University, Jocelyn Bell Burnell discovers the first pulsar. And speaking of things that pulse, South African surgeon Christiaan Barnard carries out the first human heart transplant.



1985 A hole is identified in the ozone layer over Antarctica by Farman, Gardiner and Shanklin. In the US, a team led by Howard Kroto discover the buckyball molecule.



BRIAN CLEGG is a science writer and author, whose most recent book is *Science For Life*



THE LANDS THAT MAN FORGOT

Rainforests were top of the agenda at this month's UN Climate Change Conference. But they're not the only ecosystems we ought to be protecting, as **Jheni Osman** reveals

RAINFORESTS ARE THE poster child for conservation. They're packed with charismatic wildlife and are essential for the health of the planet. Why wouldn't you want to try to save them? But they are not the only ecosystems playing a crucial role on Earth. For example, did you know that 450 billion tonnes of carbon is kept locked up by peat bogs? Or that the Sahara feeds the Caribbean with vital nutrients?

But because these ecosystems are less biodiverse than rainforests, they can be vulnerable to exploitation. And if we ignore their destruction, it could spell global ecological disaster.





GRASSLANDS



We know that chopping down rainforests is like hacking away at Earth's lungs, so we need to protect trees and plant more of

them. But experts say that poorly targeted tree planting can damage ancient grasslands and savannahs.

"As long as carbon stored in trees is valued above other ecosystem services, the conservation values of grassy biomes will remain threatened," says plant ecologist Dr Joseph W Veldman, from Iowa State University. "Threats can be direct in terms of financial incentives, such as carbon payments, and policies like fire suppression laws, which cause biodiverse grassy biomes to be replaced by low diversity forests or plantations. Then there are indirect threats – if forest is protected and/or an agricultural field is reforested, the burden shifts to unprotected, undervalued grassy biomes."

SOIL STASH

While boreal forests – those found at high northern latitudes – are the largest carbon store on the planet, temperate grasslands get the bronze medal. The UK Countryside Survey estimates that 660 million tonnes of carbon are stashed away in our grassland soils – about one-third of all soil carbon stocks in the country.

"It's vital we protect grasslands for carbon storage," says Susan Ward, Senior Research Associate at Lancaster Environment Centre. "Conservation value is not just for the plants we see, it's also for insect pollinators and for the soil communities beneath our feet."

Free-range meat and milk come from the likes of Daisy the cow, who lives off our grasslands. But many of our insect pollinators also live in this environment. Insects pollinate 80 per cent of all plant species in Europe, which is a service worth millions.

Before Europeans settled in the 'corn belt' state of Iowa, there were 125,000km² of tallgrass prairie. Today, less than 0.1 per

"Conservation value is not just for plants, it's also for insect pollinators and for the soil communities beneath our feet"

Susan Ward, Lancaster Environment Centre

FACT FILE: GRASSLANDS

34 per cent of terrestrial carbon is stored in grasslands all around the world.

60 per cent of newly forested areas in the EU were formerly permanent pasture or meadows.



40.5 per cent of the Earth's surface is covered by grasslands.

Calcareous (chalky) grasslands are Europe's most species-rich plant communities, with up to 80 plant species per m².

UNESCO defines grasslands as 'land covered with herbaceous plants with less than 10 per cent tree and shrub cover'.



There are lots of invertebrates living in this grassy field, along with the cow

cent of Iowa's original grasslands remain. In the UK, over half our grasslands are 'agriculturally improved' to maximise yield. Species-rich grasslands, such as traditional hay meadows, have been decimated; less than 3 per cent of the original meadows are left.

After WWII ended, agriculture boomed with an injection of fertilisers, which reduced plant diversity and increased atmospheric nitrogen. The knock-on effect of higher nitrogen levels is a rise in grassland growth. This reduces species richness, which threatens biodiversity.

If losing the likes of the chirping cricket doesn't bother you, bear in mind that plants or beasts lurking in the long grass could help cure nasty bugs. Back in 2013, a

new species of mushroom was discovered in the grasslands of Snowdonia. As some other mushroom species hold antibiotic properties, the discovery of *Entoloma eryriensis* put a stop to the construction of hundreds of new homes in the area.

Stopping construction locally is one thing. But how can we protect grasslands globally? "Global reforestation efforts should either constrain their 'restoration' to deforested lands or, if working in degraded grasslands and savannahs, incorporate key features of savannah-grassland restoration into their methods, such as prescribed fire," says Veldman.

Burning grasslands may sound counterintuitive, but fire is not a new

phenomenon in grassy biomes and pre-dates humans by millions of years. There's even evidence of fire adaptation in some plants. The key is to tailor the fire treatment to the land. In low rainfall areas with lots of animals, fires should be spaced out over years or decades. Other areas need more frequent fires, otherwise they rapidly turn to shrublands or forests.

"Conservation agreements should recognise the important role that fire and large herbivores play in the maintenance of biodiversity and ecosystem services in many grassy biomes," says Veldman. "I hope that old-growth savannahs and grasslands can achieve the kind of public conservation and restoration support that forests have had."



SWAMPS, BOGS AND MANGROVES



If the word 'wetland' conjures up memories of tramping through boggy ground, you may wonder why we should care about these places. Well, aside from being great habitats for many birds, amphibians and beneficial insects, wetlands could help us keep a lid on global warming.

Take the case of peat bogs. Formed over millions of years from moss, wood and dead plants, these swampy habitats can be vast – one the size of England was discovered in the Congo in 2014.

As decomposers can't survive in these wet, oxygen-poor conditions, organic matter doesn't get broken down. This means the carbon that was in the plants becomes trapped in the peat. Each square metre of peat can be packed with hundreds of kilograms of undecomposed organic matter. Research shows that about half of the peat in the northern hemisphere is made up of carbon, while up to 450 billion tonnes of the element is sequestered in peat bogs around the world – that's like stashing away 65 years' worth of our current carbon emissions from burning fossil fuels.

When peat bogs dry out, carbon is released into the atmosphere. Over the next few centuries, 40 per cent of carbon could be lost from shallow peat bogs and as much as 86 per cent from deep bogs.

Global warming won't just dry out peat bogs, it'll also cause frozen ones to thaw. Beneath the Arctic tundra lie more than 1,000 billion tonnes of carbon – double the human emissions since the Industrial Revolution. Man-made climate change has forced Arctic air temperatures to rise twice as fast as elsewhere around the planet, while permafrost temperatures have soared by 5.5°C since the 1980s.

While there have been fears that thawing permafrost could cause a sudden big 'belch' of methane and carbon dioxide to be released, recent research by the US Geological Survey found that it's more likely to be a gradual process. But the impact will be immense.

A so-called 'climate feedback loop' is what's really causing scientists to frown. If the permafrost warms up too much, some microbes will be able to decompose organic matter, releasing more greenhouse gases, warming the planet further and heating up the permafrost.

WATER HERO

Alarmed by a possible future of 'runaway global warming', some engineers are suggesting radical geoengineering solutions. But this could be too little too late. Permafrost is already thawing and what we've seen so far may just be the tip of the peat bog.

In warmer climates, mangroves are the unsung heroes of coastal habitats, storing up to four times more carbon than any other tropical forest. The secret lies in the mangrove's dense bundle of roots that anchors it in the water. Tidal water slows down as it hits the roots, reducing coastal erosion but also dumping organic material. Microbes don't decompose this material due to low-oxygen levels. Deforestation of these precious trees generates enormous amounts of carbon a year. Mangroves have a whole host of other benefits too. Not only has research shown that they protect sensitive corals from the threat of rising temperatures and ocean acidification, they've also been found to filter heavy metals and are a potential source for antibiotics.

Over the last 50 years, mangroves have been reduced by up to a half by deforestation. Sadly, protecting the habitat of the pygmy sloth or the mangrove cuckoo doesn't feature too highly on Señor's checklist when he can pull in the pesos by developing prime coastal real estate – while a wily government minister also lines their pockets.

If the little sloth doesn't tug at their heartstrings, hopefully the threat of coastal erosion and the loss of natural fish nurseries, and a pat on the back for hitting carbon emission targets, will persuade ministerial minds to give the thumbs down to new developments.

By understanding facts about ecosystems, such as drained wetlands give off the same amount of greenhouse gases as industry, some governments already see the benefits of protecting them. Over the last few decades, Sweden has built wetlands on land traditionally used for farming. Wetlands prevent surplus nutrients from leaching into lakes and oceans, protecting endangered frog and bird species. A study by Halmstad University shows that wetlands have been partly responsible for the little grebe and the little ringed plover being taken off the IUCN Red List.

The long and short of it is that wetlands are great carbon sinks, wonderful filters and a treasure trove for medicines – as well as being vital for native wildlife and local communities.



FACT FILE: WETLANDS

50 per cent of wetlands have disappeared in the last century.

67 per cent of European wetlands that existed 100 years ago have been lost.



6 per cent of Earth's land area is wetlands.

Since the 1950s, 84 per cent of peat soils have been lost in the UK due to drainage and extraction.

A quarter of the most important wetlands in Europe are threatened by groundwater overexploitation.

Lewis, in Scotland's Outer Hebrides, has a long tradition of using peat for fuel



DESERTS



Empty. Endless. Lifeless. That's what springs to mind when you hear the word 'desert'. But there's more to deserts than meets the eye.

And not all of them are hot, dry and dusty – Antarctica is a desert as it experiences less than 200mm of rainfall every year.

Climate change is playing havoc with Antarctica. Rising temperatures are creating wetter conditions, altering the soil and changing the carbon dioxide levels.

"A small increase in temperature can tip the ecosystem from frozen to melting, turning patches of desert into a wetland," says Prof Ross Virginia, Director of the Dickey Center's Institute of Arctic Studies at Dartmouth College in the US. "That makes the soil a very different kind of habitat for the organisms living there, and it can change the cycling of carbon and the release of carbon dioxide."

DESERT DEPOSIT

Just like grasslands and wetlands, deserts are also great carbon stores. The Kalahari Desert in Botswana is full of drought-resistant cyanobacteria that fix atmospheric carbon dioxide. And recent research suggests that vast, hidden aquifers could be stashing carbon.

For years, scientists were baffled by the so-called 'missing carbon sink'. About 40 per cent of carbon emissions remain in the atmosphere, around 30 per cent get soaked up by the oceans and almost all of the remainder is absorbed by plants. But a tiny bit is leftover – so where does it go?

Researchers from the Chinese Academy of Sciences recently discovered a huge lake beneath China's Tarim basin that holds 10 times more water than the North American Great Lakes.

"Our definition of 'desert' may have to change," explains biogeochemist Yan Li from the Chinese Academy of Sciences. "Atmospheric carbon is being absorbed by crops, released into the soil and transported underground in groundwater. These saline aquifers under the desert

are covered by a thick layer of sand and will never return to the atmosphere, probably becoming carbonate rocks or salt mines. It's basically a one-way trip. The nice side of this story is that this carbon sink is enhanced by human activities – irrigated farming speeds up carbon dioxide absorption."

While sandstorms were a pain in the backside for Lawrence of Arabia, desert dust is vital for many ecosystems. The AERONET project is a series of ground-based monitoring stations around the globe, which measure atmospheric aerosols. When dust is blown from the Sahara over the Iberian Peninsula, researchers have found that less radiation reaches Earth's surface than normal. Hence, desert dust cools the planet.

Saharan dust can be blown even further afield than Spain. In fact, it's known to travel across the Atlantic to the Caribbean. Once there, it supports plants with nutrients when levels are low in the ocean. Meanwhile, dust from deserts in Mongolia and northern China is blown as far away as the Pacific Ocean, where phytoplankton survive on the iron-rich dust.

"If there are changes in desert size or in the way people use land, there could be a greater source of dust to the Pacific," says Chris Hayes, from MIT's Department of Earth, Atmospheric and Planetary Sciences (EAPS). "It's difficult to predict,

but larger deserts could produce a greater source of dust to the ocean, which could potentially increase the growth of certain phytoplankton groups."

The carbon fixed by phytoplankton is absorbed by larger organisms feeding on the algae. Working its way up the food chain, carbon gets 'packaged' into larger particles, including faecal pellets, which sink down into the deep ocean. So phytoplankton growth is important for regulating Earth's climate.

"By increasing phytoplankton growth, dust could have a positive impact on the climate by drawing down atmospheric carbon dioxide concentrations," explains Hayes.

All this goes to show it's a mirage to think that deserts are empty vast plains or freezing wastelands that are only good for a *Top Gear* special. Deserts may appear lifeless, but they are in fact vital for life. ■

JHENI OSMAN is a science writer and presenter and a former Editor of *BBC Focus*

DISCOVER MORE!



To listen to an episode of *The Living World* about Ireland's peat bogs, visit bbc.in/1JF8xR3

FACT FILE: DESERTS

11 per cent is the increase in desert foliage over the last two decades. This is due to soaring levels of carbon dioxide.

20 per cent of deserts are covered in sand.



One-third of Earth's surface is desert.*

Antarctica is the world's largest desert. The only plants that grow there are mosses and algae.

China is building a 4,500km-long 'Great Green Wall' made up of 100 billion trees to try to hold back the Gobi Desert.

*Based on the definition of a desert being a region with less rainfall in a year than it gives up through evaporation.

Just 166mm of precipitation falls on Antarctica each year, which means it's classified as a desert



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GROUND CONTROL TO MAJOR TIM

Tim Peake is about to become the first British astronaut to visit the International Space Station. **James Lloyd** caught up with him on the eve of his mission

SINCE BEING SELECTED as a European Space Agency (ESA) astronaut in 2009, Tim Peake has lived underground for a week, spent 12 days in a laboratory beneath the ocean, and completed training exercises that would make Arnold Schwarzenegger weep. In 2013, ESA announced that Tim would be travelling to the International Space Station (ISS) for a six-month stint in space, becoming the first British astronaut to live and work on the orbital outpost. His time has finally come.

On 15 December, Tim will be launched into space aboard the Soyuz TMA-19M, blasting off from Kazakhstan along with fellow Expedition 46/47 crewmembers Yuri Malenchenko and Timothy Kopra. His mission is named 'Principia' in honour of Isaac Newton's masterwork of physics *Philosophiæ Naturalis Principia Mathematica* – the learnings from which will help propel the crew into orbit.

In late October, I met Tim at his base at ESA's European Astronaut Centre in Cologne, Germany to find out how preparations were going, what he'll actually be doing on the ISS, and whether he'll be able to enjoy a cup of tea in space.

DISCOVER
MORE!

**BBC
ONE**

Watch *Stargazing Live* on BBC One on 15 December to see Tim Peake blast off from Earth at 11:05am

**BBC
TWO**

Tune in to *Stargazing Live* on BBC Two in the evening of 15 December to watch Tim Peake's ship dock with the ISS





What stage are you at with your preparations?

Over the last two weeks, I've been doing some last minute training here at the European Astronaut Centre. I've signed up to 23 human physiology experiments that are going to be done on my body, so they've been collecting blood, and [performing] X-rays and MRI scans – all the kinds of medical data that we need to support those experiments.

In the next couple of months, I'll be heading to Star City just outside Moscow in Russia, where I'll be doing final training in the Soyuz simulator with my crewmates Tim Kopra from NASA and Yuri Malenchenko from Russia. We'll then be spending two weeks in quarantine in Baikonur prior to our launch into space on 15 December.

Your training programme over the past six years has been incredibly intense. Was there any point at which you had second thoughts?

I've never had second thoughts about what I'm doing. Yes, the training is tough, but I enjoy all of it. Learning the Russian language is probably the part that I've found the toughest, and at times the least enjoyable. But even with that I've struggled through and got to a happy place. We've got brilliant instructors who go out of their way to make sure that we're trained to the highest standard possible, and you really do feel the support of all the ground team.

What's been the most physically demanding part of your training?

The spacewalk training – it takes an awfully long time to train somebody how to operate in a spacesuit outside the International Space Station with all the tools and equipment. This is





James Lloyd from *Focus* presented Tim Peake with a personalised copy of the magazine

“We also expect the ISS toilet to break at some point - it’s 15 years old now”

➔ probably the most physically and mentally challenging task we have to do, but it’s also the most enjoyable.

We do our spacewalk training in a 12m-deep pool at the Johnson Space Centre in Houston. A replica of the whole space station has been sunk, and we’ll spend six hours at a time practising spacewalking. The neutral buoyancy [where the buoyancy from the water balances the force of gravity, so you neither sink nor rise] enables you to manoeuvre your body upside down or on your side into different worksite positions. Of course you still have gravity – you feel the blood going to your head and you drop down a little bit in your spacesuit – but it gives you that freedom of movement.

As a pilot, every time I put on the spacesuit and go down in the water, I see it as a flying sortie. You have to be really well choreographed. You always have to know what you’re doing next, where your buddy is and what he’s up to, but you have to be so focused on what you’re doing at the time as well.

What will be your daily routine on the ISS?

Every day will be different, but fundamentally we’re doing science and we’re maintaining the space station. It took 10 years to build the space station – we’re now well into the operating phase, and that means that science is taking over the majority of the time. I’ll be running experiments in the European and Japanese laboratories, and also carrying out any maintenance that’s needed, like replacing valves, keeping the carbon dioxide under control, and processing urine into water. We also expect the toilet to break at some point – it’s 15 years old

now, so that’s the kind of task that we’re trained for.

Which aspect of the mission are you least looking forward to?

I’ve heard that the urine transfer tasks can get a bit mundane and repetitive – constantly transferring and processing the urine on almost a daily basis [equipment on the ISS recycles urine to provide drinking water for the astronauts]. We’re working towards a 100 per cent closed, self-sufficient life support system, which is what we’d need for a Mars mission. With the water, we’re up to

Tim will act as co-pilot aboard the Soyuz rocket



around 90 per cent self-sufficiency, which is all by processing our urine back into drinking water.

What kinds of science experiments will you be carrying out on the ISS?

Some of the human physiology experiments are really exciting. We’re doing airway monitoring, looking at what causes asthma and how nitric oxide influences the airway. We’re also studying why an astronaut’s eyesight sometimes changes [in space]. There’s a theory that it could be caused by the intracranial pressure rising and pushing on the back of the eyeball, or by the increased levels of carbon dioxide on the ISS.

In the Japanese laboratory, we’re growing protein crystals for drug research. There are hundreds of thousands of proteins in the human body, and some of them are disease-causing. In order to find a drug to counter these proteins, it needs to fit like a jigsaw puzzle piece. If you try to grow proteins on Earth, there’s sedimentation [where protein molecules settle due to gravity] and convection [where differences in density set up currents in the fluids], so you get tiny crystals which are very impure, and the drug which fits the crystal isn’t that effective. In space, you can grow big, very pure crystals, so you get great drugs to fit that disease.

In the Japanese segment, I’ll be installing an electrostatic furnace. This is designed to burn small pellets of metal alloys and composite materials, so that we can investigate their melting, cooling and crystallisation properties. In microgravity, you can create new materials that you can’t create on Earth. We’re looking into how we can make aircraft and car engines cleaner and more efficient,



LIFE ON THE ISS

Eating, sleeping, going to the toilet... even the most mundane of activities takes on a new life in space. Here's how ISS astronauts go about their day-to-day business



GOING TO THE TOILET

Visiting the loo in microgravity is completely different to going on Earth. The two ISS toilets use

fan-driven suction systems to prevent any nasty mishaps. Poo goes into plastic bags and is stored in an aluminium container. Urine is collected, then processed into drinking water.



EATING

Space food has come a long way since the insipid pastes of yesteryear. Astronauts today can

choose from a range of foods, including fresh fruit, vegetables, meat, rice, tortillas, soup and brownies. Tim Peake will be going one better, tucking into a British-inspired menu developed especially for him by Heston Blumenthal.



DRINKING

As well as drinking recycled urine, astronauts can enjoy coffee and tea on board – supplied as freeze-dried

mixes – and a variety of flavoured drinks and juices. Some of the drinks sipped by Chris Hadfield aboard the ISS included tropical punch, cocoa, mango-peach smoothie and apple juice. Yum.



SLEEPING

Astronauts get some shut-eye in one of the six small sleep stations scattered throughout the ISS. A

sleeping bag fastened to the wall provides a secure cocoon for the tired space-venturer. The astronauts get to see 16 sunrises a day as they circle the Earth, so they might need to wear an eye mask to keep out the light.



KEEPING CLEAN

The morning routine becomes a little more complicated in space. There's no shower on the ISS, so astronauts use no-rinse shampoo to keep their tresses tidy, and a damp, soapy cloth for washing.

Toothbrushing is achieved using a water bag plus toothbrush and toothpaste. Astronauts have to swallow rather than spit – you don't want globules of saliva floating around the place.



ESA's Columbus Laboratory on the ISS offers a weightless environment for experiments





Tim Peake has completed a gruelling schedule to prepare for his ISS visit. From L-R: underwater spacewalk practice; survival expeditions; cave exploration; Soyuz simulations; landing drills

1998

Successfully qualified as a helicopter flying instructor.

1994

Awarded Army Flying Wings, qualifying as a pilot.

1992

Graduated from Sandhurst as an officer in the British Army Air Corps.

1990

Completed education at Chichester High School for Boys.

minutes, so we'll see every country celebrate New Year's Eve. What better place to witness that than from space?

Looking back, was there a particular moment when you decided you wanted to be an astronaut?

The actual decision was when the European Space Agency had their selection process – up until that point, the opportunity didn't really exist. Helen Sharman [the first Briton in space] had a wonderful opportunity in 1991, which was a commercial venture that sent her and her backup Tim Mace to Russia to study as cosmonauts.

The only other route for a Brit to become an astronaut was to do what the likes of Mike Foale, Nick Patrick and Piers Sellers did and take up American citizenship in order to fly with NASA. So when I saw in 2008 that ESA had opened up the application for Brits, I applied straight away.

Will we be seeing more British astronauts now?

Absolutely. Since my selection, the UK has joined ESA's human spaceflight

→ and how we can more effectively burn things with fewer pollutants.

How will you be celebrating Christmas Day in space?

It's just another day at the office for us, but the astronauts always have a bit of fun. Believe it or not, there's a small Christmas tree already up there, there are some Santa hats, and I think a Christmas pudding is being flown up in time for us. So we'll definitely have a celebration.

New Year's Eve is going to be a lot of fun. We go around the Earth every 90

TIM PEAKE'S CV

From sleepy Chichester to an orbital outpost 250 miles above the Earth – it's been a long journey for Tim Peake.

7 April 1972

Born in Chichester, England.





2002-2005

Served as an Apache helicopter instructor.

2005

Graduated from the Empire Test Pilots' School at MoD Boscombe Down.

2006-2009

Served as a helicopter test pilot with Rotary Wing Test Squadron.

2009

Retired from the army as a major. Selected as ESA astronaut.

2015

Becomes first British astronaut ever to visit the International Space Station.



programme, so the opportunities for Brits to become more involved in human spaceflight are excellent.

Do you think your mission marks the beginning of a new era for British space exploration?

I do, genuinely. We've probably got about 10 years left of the International Space Station, and then we're well into the realms of looking at lunar exploration as a stepping stone to Martian exploration.

The UK is brilliant at robotics, which will form a very large part of the lunar and Martian missions. So I think in terms of scientists, industry and astronauts, it's the right time for us to get very involved.

Will you have the chance to travel to Mars yourself?

Unfortunately, looking at the timelines, the Red Planet is going to be outside of my career frame, which is why I'm really excited when I talk to teenagers and schoolkids – they're absolutely golden for that kind of opportunity. I might be in the right career time for a lunar exploration in the late 2020s. I'd love to do a lunar mission, but of course the competition would be fierce, so we'll just have to wait and see what happens.

If you met a teenager who was desperate to become an astronaut, what advice would you give them?

Lots of teenagers have been writing and asking that very question, and I honestly think that the most important thing is to work out what you want to do. Sure, you want to be an astronaut, but put that to one side for a minute. Nobody becomes an astronaut age 19 – you need to go and do something for 10 years minimum. That might be an engineer, a scientist, a schoolteacher, a medical doctor, but do

"I'm looking forward to enjoying a cup of tea normally, rather than having to suck it through a straw!"

not let the astronaut job really influence that decision. It's most important to do what you're good at and what you're passionate about, and that will naturally lead you to becoming an astronaut, if that's what you want.

Do you have any immediate plans following this mission?

At the moment, my focus is on the mission, but of course I've thought about what life will be like afterwards. The initial priority is to go through the rehabilitation and get back to full fitness as quickly as possible, and to use my experience to assist with all the other spaceflight programmes we've got going on, contributing and planning for future missions.

Chris Hadfield famously took his guitar into space, and Italian astronaut Samantha Cristoforetti took an espresso machine. Are there any items that you plan to take with you to the ISS?

A teacup! In fact, it's already up there. A NASA astronaut called Don Pettit worked out the exact angles you'd need for a cup in space to hold liquid without it leaving the cup and floating away [the liquid is kept in the cup by its surface tension]. So I'm looking forward to enjoying a cup of tea normally, rather than having to suck it through a straw! ■

PHOTO: ESA/MS

CAN'T GET YOU OUT OF MY HEAD



e Comes The Hotstepper Jurassic Park theme I

The Smiths - Hand In Glove N.E.T.

2 - On A Ragga Tip Big Bill Broonzy - I'm A Man
Age Of Ba

Christmas is the inspiration behind many catchy jingles. But why are certain tunes so impossible to erase from your mind? **Hayley Birch** explains...

THE FOCUS TEAM'S EARWORMS

Ever since we decided to run this feature, we've been comparing notes on the tunes that lodge themselves in our heads. We now bequeath them to you, dear readers

1-800-HOTLINEBLING
1-800-HOTLINEBLING
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1-800-HOTLINEBLING
1-800-HOTLINEBLING
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DRAKE
HOTLINE BLING



"I am not a Drake fan. While this probably doesn't keep the singer/songwriter up at night, it does make the fact that his latest single is seared onto my brain that little bit more galling."

Daniel Bennett, Acting Editor

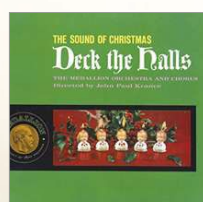


SISQÓ
THONG SONG



"I didn't like *Thong Song* when it first came out, so it seems particularly cruel that this 90s atrocity is the one tune that never fails to ping into my brain. And singing it out loud in work takes quite a bit of explaining."

Alice Lipscombe-Southwell, Production Editor



THOMAS OLIPHANT
DECK THE HALLS



"The Christmas carol *Deck The Halls* is the worst for me. I even find myself humming different arrangements: there's a lounge version, a chiptune version and so on, all of which exist only inside my head."

Russell Deeks, Contributing Editor



AMY WINEHOUSE
REHAB



"Every time that anything bad happens to me, the words "no, no, no" repeat through my head. What makes it worse is that I'm not even an Amy Winehouse fan! Argh!"

Alexander McNamara, Online Editor



THE MUPPETS
THE MUPPET SHOW

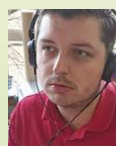


"I often find myself squeezing my lips together to form a mouth trumpet before blasting out *The Muppet Show* theme. It's strange to think that it has been lingering in my subconscious for over 30 years."

Jason Goodyer, Commissioning Editor



JOHN WILLIAMS
JURASSIC PARK THEME



"Duh duh duuuh duh duh.... Since I was nine years old, not a day has gone by that I haven't whistled this melancholic masterpiece. Maybe the *Jurassic Park* pyjamas aren't helping."

Joe Eden, Art Editor



KISS
CRAZY CRAZY NIGHTS



"What started out as a bit of a guilty pleasure for me has now become this dreadful earworm that's maliciously bored its way deep into my psyche. Crazy nights indeed."

James Cutmore, Picture Editor



BEIRUT
NO NO NO



"As much as I love this band, their recent single is probably the most earworm-y song I've ever heard. Thankfully, it's nowhere near as annoying as 2 Unlimited's similarly-titled 90s banger."

James Lloyd, Editorial Assistant

THE DEAD OF night was upon Barry Murray. The sports nutritionist and ultra-marathoner had been running for 18 hours, give or take. Right now, he was experiencing one of his earworms – tunes that would play over and over in the jukebox of his mind. Mos Def's *Ms Fat Booty* was currently giving him a lift, driving him through the difficult miles. In previous races, *Use Me* by Bill Withers

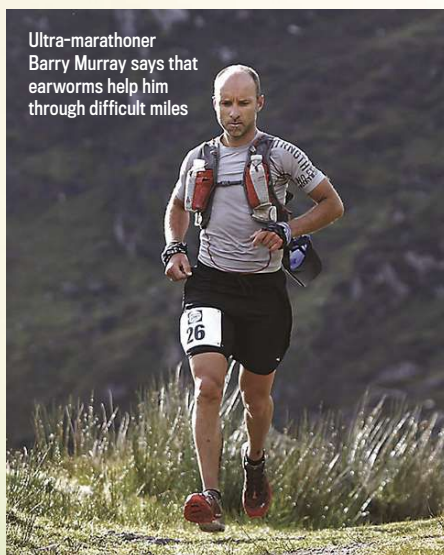
had helped him along. "That's the song that rings in my head," explains Murray, who insists he never eats breakfast before racing. "It has done so for a few years now, during every ultra I have run."

While the mental effort required to run 200km across the trails and mountain passes of County Kerry is unimaginable to most, we're all familiar with a song that gets stuck in your head – whether it's helpful, or just plain annoying. As many

as 90 per cent of us, according to estimates, suffer from an earworm at least once a week.

Murray went on to win the Kerry Way Ultra, with a time of 26 hours and 36 minutes. His story suggests there might be a point to these musical intrusions. Perhaps, though, they're just by-products of ordinary thought processes. This is one of the puzzles that Dr Lauren Stewart, a psychologist at Goldsmiths, University of

elis - Milkshake - Ginger Rogers - Cheek To Cheek Rodgers & Hammerstein - Kool & The Gang - Jungle Boogie The B-52s - Rock Lobster
 Fred Astaire & Ginger Rogers - Moby - Natural Blues TLC - Waterfalls Hall & Oates - I'm Gonna Wash That Man Right Outta My Hair Frantz



Ultra-marathoner Barry Murray says that earworms help him through difficult miles

"It's not random - the songs you get depend on your internal state"

Dr Lauren Stewart, University of London



→ London, is trying to solve. Stewart and her team in the Music, Mind and Brain Lab study 'involuntary musical imagery' - earworms, to you and me. So what have they discovered?

WORM INVASION

Some of the team's first data came via a link with Shaun Keaveny's BBC 6 Music breakfast radio show. "I heard their feature called *Earworms*," remembers Stewart. "They got people to text in with whatever tune they had going around in their head. So I contacted the show and asked if they could share some of their data with us." The show sent earworms from thousands of listeners. More than

300 of them had also described how their earworms started, providing some of the data for a 2012 study on earworm triggers. No surprise that the most common trigger was listening to the very song that then got stuck.

But people also connected songs to particular words, situations and even well-known personalities. One listener, for example, described hearing *This Charming Man* by The Smiths every time David Cameron appeared on the TV.

Since then, Stewart's group has delved further into why and how songs get stuck in our heads, and tried to understand why some people experience earworms more frequently than others. One theory, backed up by the results of one of their surveys, suggests that people with obsessive-compulsive personality types may be more susceptible to earworms. The team also has found that non-musicians seem to be just as likely as musicians to pick up earworms. Surprising, perhaps, but neuroscientist Dr Steven Brown at McMaster University in Ontario believes the same is true of

those who experience the phenomenon of what he calls 'perpetual music track' - a kind of extreme earworm syndrome.

Brown himself is a pianist and has had segments of music looping in his head on a near-constant basis for as long as he can remember. Around a decade ago, he decided to conduct a self-analysis, which was published in the *Journal Of Consciousness Studies*. Since he published it, he's received emails from around another 70 people with similar symptoms. But there's no common thread, he says. "I thought it was going to be limited to people who actually work with music but it's quite diverse. I mean, there are people like me and there are also people who say they have no exposure beyond just listening to music passively. So I don't see any trends yet, whether for gender, age, experience or the like."

BRAIN STUDIES

Just this year, though, Stewart and her colleagues published the first



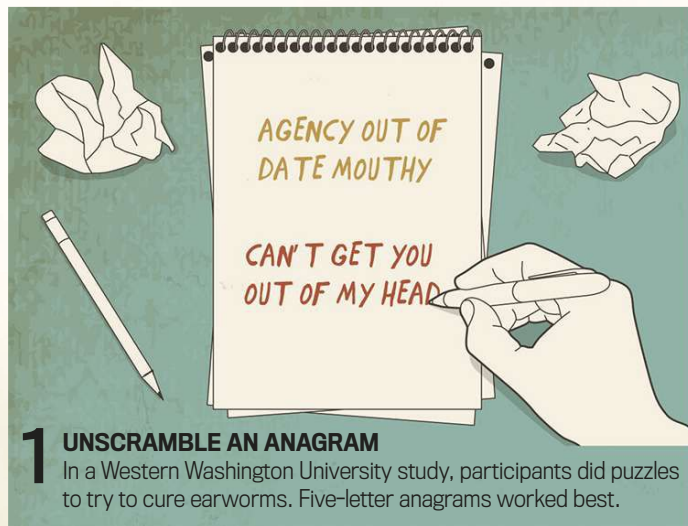
Neuroscientist Dr Steven Brown is plagued by looping music, rather than songs with lyrics



ter - as - Yanv - Beirut - No No No Aqua - Barbie - G-falls - Hall & Oates - Maneater Battles - Futura - Kool & The Gang - Halfway To Paradise
 ss - elis - Milkshake Moby - Natural Blues TLC - Water - REM - The End Of The World As We Know It Billy - The Gang - Jungle Boogie

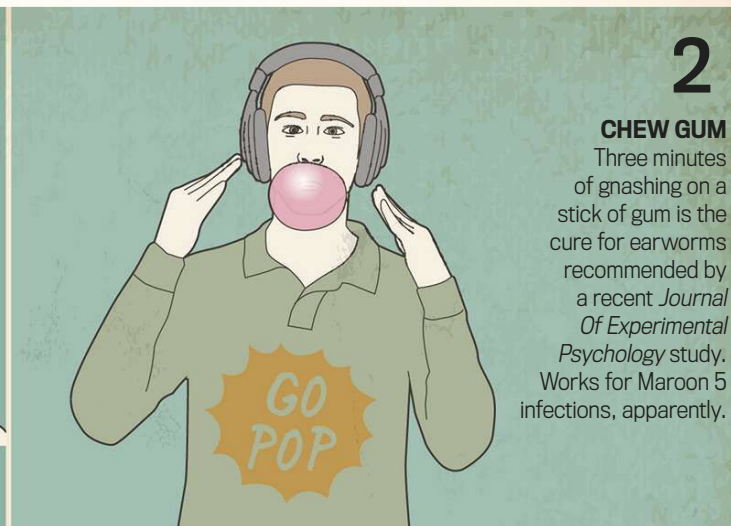
HOW TO GET RID OF AN EARWORM

Six techniques for getting that ruddy song out of your head



1 UNSCRAMBLE AN ANAGRAM

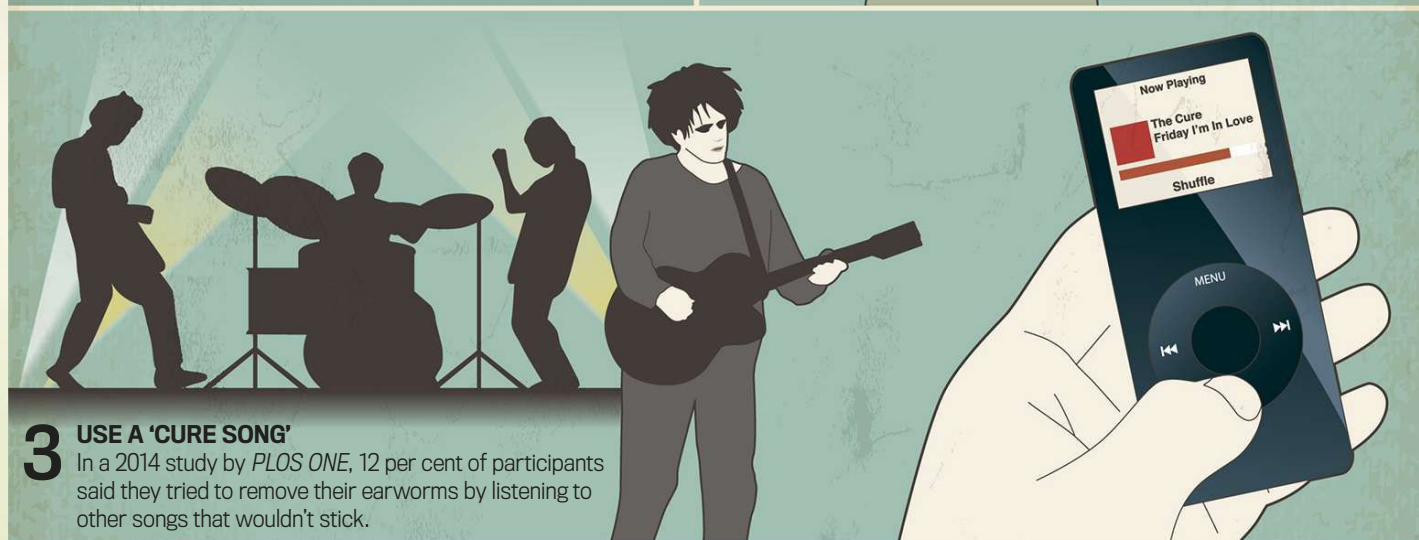
In a Western Washington University study, participants did puzzles to try to cure earworms. Five-letter anagrams worked best.



2

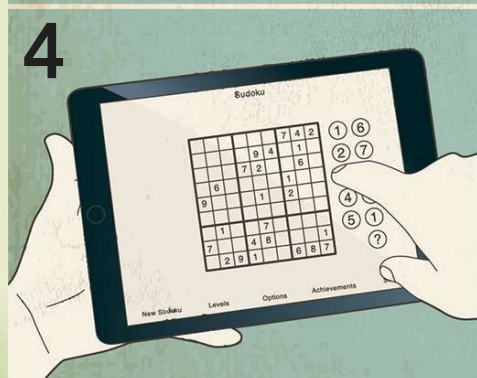
CHEW GUM

Three minutes of gnashing on a stick of gum is the cure for earworms recommended by a recent *Journal Of Experimental Psychology* study. Works for Maroon 5 infections, apparently.



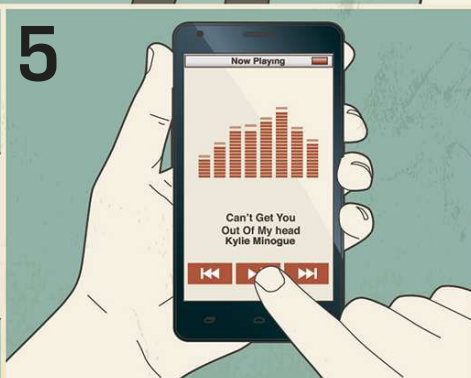
3 USE A 'CURE SONG'

In a 2014 study by *PLOS ONE*, 12 per cent of participants said they tried to remove their earworms by listening to other songs that wouldn't stick.



SOLVE SUDOKUS

Western Washington University found that sudoku puzzles worked, but only if they were of an optimum difficulty level.



JUST PLAY THE DAMN THING

Some people insist that the best way to deal with an annoying snippet of music is to listen to the offending tune in its entirety.

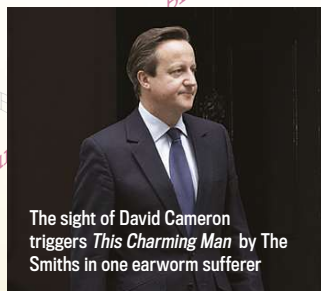


REPLACE IT

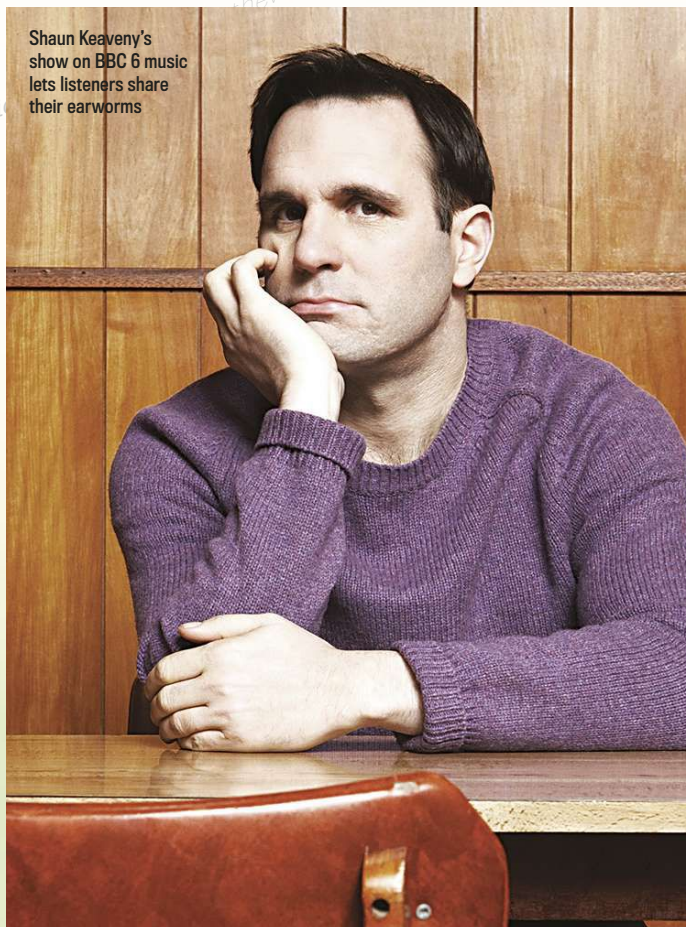
The site unhearit.com claims to help you 'unhear' songs by playing you equally catchy ones. Presumably some sort of sick joke...

Simon & Garfunkel - The Only Living...
 eefheart - Tropical Hotdog Night The Whi

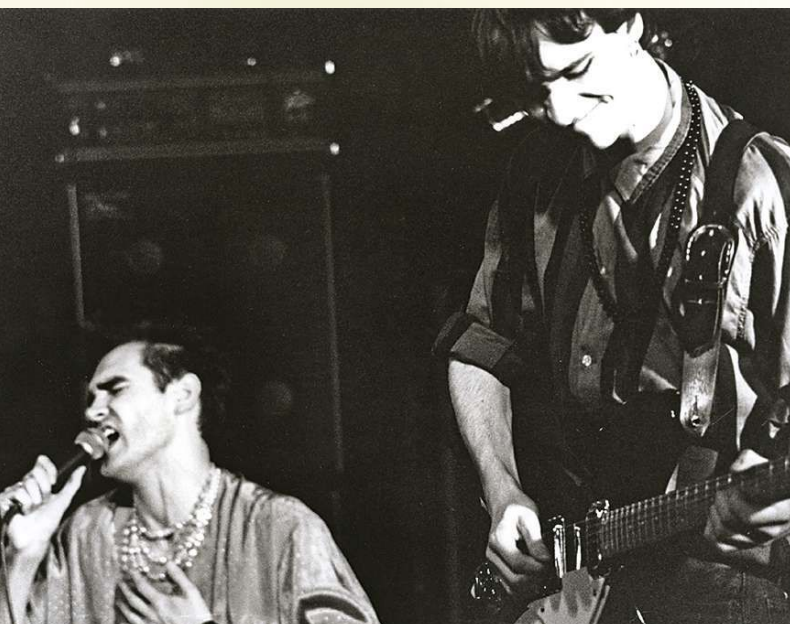
Brand New Combine Harvester Mississippi John Hurt - Do Lord Remember
 shews Southern Comfort - Woodstock Roger M
 the INXS



The sight of David Cameron triggers *This Charming Man* by The Smiths in one earworm sufferer



Shaun Keaveny's show on BBC 6 music lets listeners share their earworms



➔ scientific study of links between brain structures and earworms. They quizzed 44 people about their earworm experiences, then put them in a brain scanner. The results showed differences in grey matter thickness in certain regions of the brain, correlating to how often people got music stuck in their heads, as well as how problematic or annoying they found the music.

All this suggests that everyone experiences earworms or musical imagery in different ways, but that what causes these differences may not be obvious without probing deep inside the human brain. What really intrigues Stewart is the idea that earworms could actually be good for us. Her working hypothesis is that earworms and other spontaneous thoughts could play a key role in stabilising consciousness.

"I like to think of it as a homeostatic [regulatory] function. If your consciousness slips too low, you're in all sorts of trouble because you're not vigilant to the dangers around you," she explains, referring to Oliver Sacks' near-death experience on a mountain (see 'Five famous earworms', p63). "So these internal thoughts might provide enough



stimulation so that you're maintaining an optimal level of vigilance."

The theory is partly supported by another 2015 study from the Goldsmiths group that shows how the tempo of internal tunes complements our mood or arousal level. Each volunteer was asked to wear an accelerometer on their wrist for four days and to tap to the beat of their earworms on their leg. The accelerometers would record the taps. For every earworm, the participants also noted down the kind of mood they were in - upbeat, say, or a bit sluggish. Overall, there was a link between people's states of arousal and the tempo of their earworms. As Stewart explains, "It's not random - the songs you get depend on your internal state." So whether it's

According to psychologist Dr Jonathan Smallwood, we have more spontaneous thoughts in undemanding environments

the state to the song or the song to the state, there's some sort of matching process going on.

For Stewart, earworms are a model for mind-wandering more generally, and this most recent study suggests spontaneous thoughts while the mind is wandering may help to balance arousal levels. But is there any wider support for such a brain-balancing role?

Dr Jonathan Smallwood, a psychologist and mind-wandering expert based at the University of York, thinks there could be something in it, albeit in a slightly different sense. He cites evidence that shows people have more spontaneous thoughts when their environment is uninteresting or demands little attention. "Under these situations, people often

Killer - Whistle Stop 2 Unlimited - No Limits Evanescence - Bring Me To Life 5 Club 7 - Bring It All Back Arcade Fire - No Cars Go
 3 - Never Tear Us Apart Julian Nott - Wallace & Gromit Theme Merle Travis - Nine Pound Hammer

spontaneously devote conscious attention to other matters, such as events in their future," he says. "This implies that people use their idle moments to make progress on goals, which is a bit like a homeostatic function."

MAKE IT STOP!

Whether involuntary musical imagery has a helpful role to play or not, how we perceive it seems to be a very personal matter. Brown has learned to live with his internal music but claims that many of those who have written him emails about their own just want him to make the music stop.

Similarly, in the course of her research, Stewart has come across plenty of people who are plagued by their earworms, like the woman who said that the theme tune from the 1980s cartoon *DuckTales* was driving her mad. Yet her team's survey results also suggest that some people find earworms are useful for completing particular tasks. Perhaps Barry Murray is just one of those people. ■

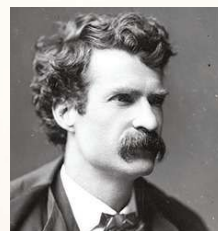
HAYLEY BIRCH is a freelance science writer and co-author of *The Big Questions In Science*



DuckTales:
Tunnelling
into minds
since 1987

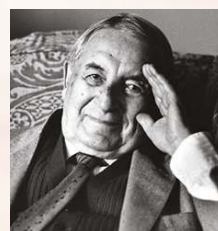
FIVE FAMOUS EARWORMS

People have been struggling to cope with catchy tunes for decades – it's not just a modern phenomenon



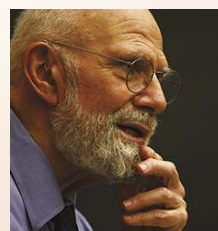
1 A LITERARY NIGHTMARE

Mark Twain's short story *A Literary Nightmare* (1876) tells of a town afflicted by a jingle-like poem. The jingle was based on a real-life information sign about tram tickets, hence "Punch brothers! Punch with care! Punch in the presence of the passenjare!"



2 MELODIC PATTERNS

The early 20th-Century Russian-born composer Nicolas Slonimsky identified patterns in music that could "hook the mind and force it to mimicry and repetition" in his 1947 book *Thesaurus Of Scales And Melodic Patterns*.



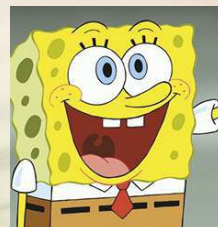
3 VOLGA BOATMEN

The late neurologist Oliver Sacks once injured his leg badly while escaping an enraged bull on a mountaintop. In *A Leg to Stand On* (1984) he explains how the rhythm of *Song Of The Volga Boatmen* kept him conscious as he slid himself to safety.



4 SURFIN' BIRD

Peter Griffin's annoying 'bird' is the word' earworm in a 2008 episode of *Family Guy* became so strongly associated with the animated sitcom that many younger viewers thought it originated from the show. It was actually 1960s hit *Surfin' Bird* by The Trashmen.



5 MUSICAL DOODLE

An episode of Nickelodeon's *SpongeBob SquarePants* that aired in 2010 was called 'Earworm'. In the episode, the character SpongeBob SquarePants became infected by a living creature that transmitted a catchy tune called *Musical Doodle*.

DISCOVER MORE!



To listen to an episode of *The Why Factor* on earworms, visit bbc.in/1U80Qt5



To hear our Ultimate Earworm Playlist visit bit.ly/UlimateEarwormPlaylist



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BY OUR JEDI PANEL



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Susan is Visiting Professor at the University of Plymouth. Her books include *The Meme Machine* and *Ten Zen Questions*



DR ALASTAIR GUNN

Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester



ROBERT MATTHEWS

After studying physics at Oxford, Robert became a science writer. He's a Visiting Professor in Science at Aston University



GARETH MITCHELL

Starting out as a broadcast engineer, Gareth now writes and presents *Click* on the BBC World Service



LUIS VILLAZON

Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach The Ground*

EMAIL YOUR QUESTIONS TO questions@sciencefocus.com

or post to *Focus Q&A*, Tower House, Fairfax Street, Bristol, BS1 3BN

Why are Stormtroopers so useless?

A IT'S BECAUSE THEY'RE a clone army. Among soldiers, valuable qualities include courage, adaptability, persistence and average intelligence. Loyalty, discipline and willingness to follow orders are crucial. The clones might all fit this profile but a fighting unit needs variety when facing unexpected challenges. There are also specialist duties, from technical tasks and communications to maintenance and procurement. Clones designed for fighting would not be suited to these, nor to being commanding officers. These roles require high intelligence and leadership qualities that might be positively disruptive in a Stormtrooper. **SB**



PHOTO: LUCASFILM LTD/IMAGE.NET



Opting into the Dark Side didn't do Darth Vader any favours



Emperor Palpatine had fallen asleep in the bath again

Is being evil bad for you?

A BEING BAD, CRUEL or even evil makes some people feel good in the short term. Fighting and hurting others can be exciting, give a feeling of power, or make bad people feel superior when they see someone else suffering. But the longer lasting effect is quite the opposite. Research shows that doing good makes people happy, and being happy makes people do good. So there's a virtuous cycle of kindness and generosity. Caring for others helps people to feel better about themselves and this is a lasting source of happiness. Even remembering kind deeds you have done in the past can make you smile. Happy people live longer too, although the causes are not yet clear. Health and happiness may affect each other, and a healthy lifestyle with lots of exercise and good food increases both. So don't envy the baddies their thrills. They will probably pay for it later. **SB**



Han Solo's mouth and throat anatomy may mean that he's physically incapable of speaking Wookiee

How could we talk fluently to aliens?

A THE SAME WAY that the early explorers and missionaries learnt the native languages of Southeast Asia and South America. You begin with pointing and other gestures, and slowly build from there. Children younger than five are much better at this than older kids and adults, so we could

train a generation of interpreters by raising children in a mixed human and alien environment. If the aliens were particularly strange, we might not actually be able to speak their language at all. Han Solo and Chewbacca can understand each other, but Han never speaks a word of Wookiee. **LV**



What would faster-than-light (hyperspace) travel look like?

A IN THE MOVIES, stars stream out into long trails as a spaceship travels through 'hyperspace' or uses its 'warp drive'. Unfortunately, because these concepts are entirely fictional, usually involving alternative universes or extra dimensions, science can say very little about what 'real' hyperspace travel might look like. However, if we regard hyperspace travel as the ability to travel at almost the speed of light, we can categorically dismiss the idea of stars elongating as shown in *Star Wars*

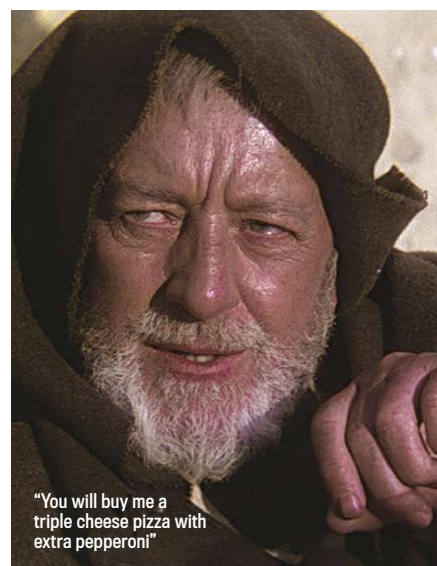
and other movies. In fact, as your speed increased, you would see the stars fade and eventually disappear as their light is redshifted into the X-ray part of the spectrum, which is invisible to the human eye. The starlight would be slowly replaced by a diffuse glow, concentrated towards your direction of travel, caused by the cosmic microwave background (the leftover radiation from the Big Bang which fills the entire sky) being redshifted into the visible part of the spectrum. **AG**



The films lied to us. Hyperspace travel doesn't look this cool



"Ten per cent off this new walking stick you will give me"



"You will buy me a triple cheese pizza with extra pepperoni"

Are there any real-life Jedi mind tricks?

A MANIPULATING OTHERS INTO believing that "these are not the droids you're looking for" is certainly possible in a limited way. The psychological manipulation techniques carried out by Jedi Master Derren Brown are an example of this. Martial arts experts can also sometimes detect an incoming strike and block it, even with their eyes closed, simply from the tiny sounds and pressure changes in the air. **LV**

WHAT IS THIS?

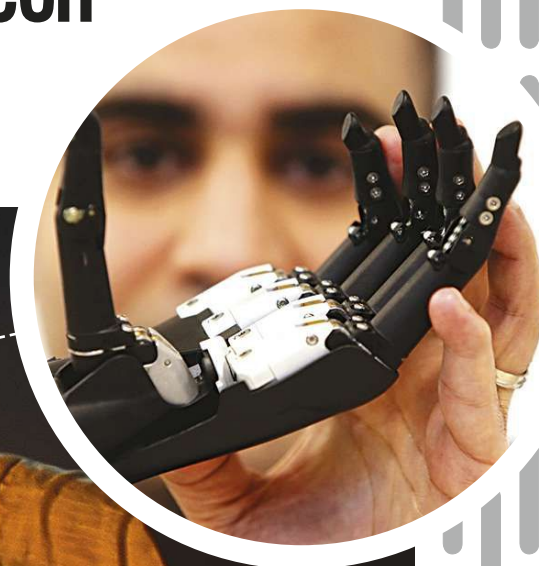
LAST MONTH'S PICTURE

Michelle Robertson correctly guessed an olive plantation in Cordoba, Spain



Will we see *Star Wars* tech in the real world?

Prosthetics used by the Skywalker family are on their way



Prosthetic robotic arms

ANAKIN SKYWALKER'S NIFTY 'mechno-arm' and Luke Skywalker's robotic hand rely on two-way communication between the brain and the prosthesis: not only must the arm obey signals to move, grip, or swing a lightsaber, but it also needs to send signals back about textures, temperatures and other sensations. The first such prosthesis became reality in autumn 2015, thanks to research at Johns Hopkins University.

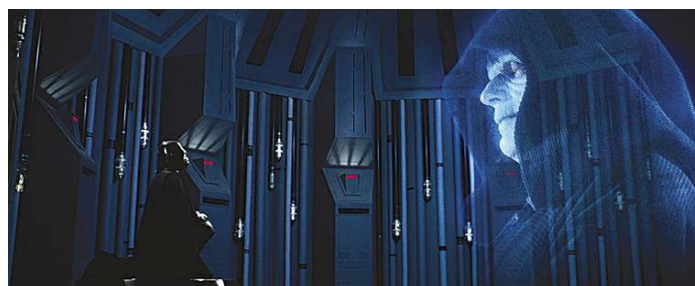
Their mechanical hand was fitted to a 28-year-old who'd been paralysed for more than a decade. Wires linked the hand to the wearer's motor cortex – the part of the brain that controls movement – as well as the sensory cortex, responsible for identifying tactile sensations. This allowed the wearer to control their hand with thought, but also to 'feel' which of the hand's fingers was being touched.

Pepper isn't up to R2-D2 standards



Emotional robots

WHEN IT WENT on sale in summer 2015, Pepper was hailed as the first emotional robot. Its makers, Aldebaran, claim that Pepper can analyse your facial expressions, body language and speech, then changes its behaviour according to your mood. It doesn't, however, display the true artificial intelligence of C-3PO or R2-D2 – that's at least several decades away. Still, people can form emotional attachments to pets. Pepper is not much more expensive than a pedigree dog, and far less messy.



Holograms

THE HOLOGRAMS IN *Star Wars* are snazzier than the stuff we've seen in reality. Sadly, holographic messages like Leia's to Obi-Wan Kenobi are still science fiction. Yet holo-games may be just around the corner. Researchers at Swinburne University have developed a system that shines a pulsed laser on a flat graphene surface to create pop-up, floating 3D images. This would be perfect for board game/video game hybrids and communications – as long as you have a graphene dining table.

Could you imagine video-calling your nan on one of these things?

Lightsabers

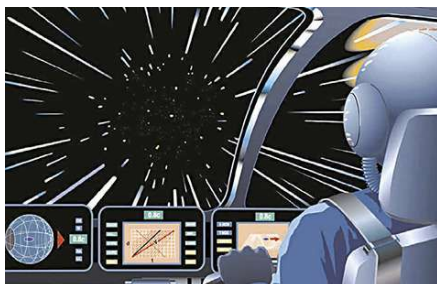
WITH POWERFUL LASERS, it is possible to build a handheld lightsaber. It would be short-range, though not quite limited to the one-metre beam of the films. It couldn't sever an arm, nor could it cut through steel doors, but

it could start fires or burn the skin. In 2013, Harvard University researchers managed to make photons of light behave like a lightsaber, by manipulating them so they acted as a solid. However 'lightsabers' made in this way would just bounce off each other. If you want to slice bits off a Sith Lord,

try a regular, old-fashioned, two-handed sword (eyewitness accounts of medieval battles say they cut through the limbs and even torsos of unarmoured combatants). When the Trade Federation locks you in a steel vault, reach for your thermal lance instead, but expect it to take a few hours to burn through the door.



My lightsaber's better than your lightsaber



Faster-than-light hyperdrives

FASTER-THAN-LIGHT (FTL) travel is the biggest gulf between reality and science fiction. As far as scientists know, the speed of light can't be surpassed. But according to Harold "Sonny" White at NASA, FTL travel is theoretically possible – he suggests using a warp drive to distort space-time around a craft, bending the laws of physics. But with colossal amounts of energy required, and no tangible results so far, humans will have to stick to slower spacecraft for now.



Antigravity landspeeders

THE LANDSPEEDERS AND speeder bikes in *Star Wars* work using 'repulsor fields' – a kind of antigravity. Scientists working on the ALPHA experiment at CERN have investigated whether antimatter – particles with the same mass as ordinary matter but opposite charge – might 'fall upwards', exhibiting a kind of antigravity. So far, however, there have been no conclusive results, so if you want a fast, floor-hugging chariot, your best bet is a ground effect vehicle. Looking

If we had a landspeeder, we'd at least give it a decent paint job

like a cross between an aircraft and a hovercraft, these use the aerodynamic interaction between the vehicle's wings and the surface to fly just a few metres above the ground. We can't promise you'll look as cool as you would in a landspeeder, though.

IAN STURROCK is a lecturer in game studies and visual effects at the University of Hertfordshire, but is not a Jedi yet

Why do some Starfighters have X-wings?

A THIS ONE HAS kept hardcore *Star Wars* fans arguing for years – because the plank-like X-wings aren't aerodynamically shaped, and aerodynamics are irrelevant in the vacuum of space in any case. Apart from looking great, one possible scientific explanation for their use is to provide a Starfighter's weaponry with extra cooling surfaces. **RM**

What is a parsec?

A HAN SOLO TELLS Luke Skywalker and Obi-Wan Kenobi that the Millennium Falcon “made the Kessel Run in less than 12 parsecs”. Unfortunately, like the similarly misused ‘light-year’, the parsec is a unit of length, not of time.

A parsec is equal to about 3.26 light-years or roughly 31 trillion kilometres (19

trillion miles). The unit has its origins in one of the first methods of determining the distance to the stars. Using the principle of parallax, some stellar distances can be found by measuring their tiny shift in position as the Earth undergoes its yearly orbit around the Sun. This only works for relatively nearby

stars. One parsec is defined as the distance at which one astronomical unit (the average distance between the Earth and Sun) subtends an angle of one arc-second. The nearest star, Proxima Centauri, is about 1.3 parsecs away, while the Milky Way is more than 31,000 parsecs across. **AG**





Coruscant: a nightmare for air traffic control

Will the Earth ever become a city planet?

A CORUSCANT, WHICH IS the capital of the *Star Wars* Galactic Empire, supposedly has a population of around three trillion. This is about 430 times Earth's current population, but even this wouldn't be enough to create a proper city planet.

To give all of Earth's landmass the same population density as Tokyo, you would need 895 trillion people, or 300

Coruscants. Even the more pessimistic projections from the United Nations suggest that the Earth's population will peak at less than 100 billion people by the end of this century. Spread across all the land area on the planet, that would give the world an average population density lower than that of Barnsley, South Yorkshire, which is hardly a skyscraper-filled metropolis. **LV**

What are the odds that aliens are humanoid?

A ANY ANIMAL THAT can move about will naturally have a front end and a back end. Sensory organs such as eyes will tend to evolve at the front of the body because they are most useful there. Lifting the body up on legs reduces friction with the ground and legs are easier to coordinate if the left and right sides are symmetrical.

If the creatures from other planets are sentient, then it's reasonable to suppose that they also make and use tools to interact with their environment. That requires at least one limb to hold the object and another one to hold the tool. To keep their hands free while they move, these aliens would need at least another two limbs. Put all that together and you have a humanoid shape with two arms, two legs, a head and all the other



vital internal organs in a central torso. But it's easy to imagine lots of other possibilities too. A civilisation of sentient octopuses, for example. Or a race descended from starfish, which walks on two legs and has three others available to interact with the world.

Palaeontologist and evolutionary biologist Prof Stephen Jay Gould said

that even if we "re-ran the tape" of evolution here on Earth, life could end up looking different to how it looks now. On an alien planet, with higher gravity, animals might need more legs to remain stable. And aliens that float in the clouds of a gas giant might be covered with eyes that can see gamma rays, to spot danger approaching from any direction. **LV**



Is it possible to create protective force fields?

A DEFLECTOR SHIELDS ARE featured in spectacular fight scenes in the *Star Wars* movies, but the idea of generating force fields at will can be found in science fiction from the 1930s. Turning it into science fact has proved a major challenge, however.

Research is split into two basic areas: creating fields to protect against blast and radiation, and using them to defend against physical weaponry like shells. Earlier in 2015, the US aerospace company Boeing revealed it has been investigating the possibility of building a force field generator able to protect military vehicles against explosive shockwaves. It's not just the shrapnel from mines and improvised bombs that

causes damage: the rapidly expanding gas that they produce can also wreak havoc. The Boeing system is designed to detect the incoming blast and rapidly heat the air near the vehicle, deflecting or absorbing the shockwave's energy. Exactly how this will be done isn't clear – though Boeing thinks that powerful lasers might work.

Force fields capable of stopping physical weaponry have also been studied, with the US Army Research Laboratory having looked at the use of powerful electromagnetic fields capable of robbing incoming shells of some of their energy. Again, however, such 'smart armour' has yet to see deployment. **RM**

COLIN STUART is a science and astronomy writer and author

REAL-LIFE STAR WARS WORLDS

Sometimes the truth can be just as strange as fiction. The *Star Wars* universe has been captivating audiences for decades, but astronomers are beginning to find alien worlds that bear an uncanny resemblance to the planets dreamt up by George Lucas, says
Colin Stuart

1. Tatooine/Kepler-16b

Appearing in every *Star Wars* movie except *The Empire Strikes Back*, Tatooine is a desert planet and the home of Luke and Anakin Skywalker. In *A New Hope*, an iconic scene shows Tatooine's twin suns setting over the horizon. Astronomers have found several examples of planets orbiting in these so-called 'binary systems'. The most famous is Kepler-16b – a real-life Tatooine.

2. Hoth/OGLE-2005-BLG-390Lb

In *The Empire Strikes Back*, the rebels set up their base on the snowy planet of Hoth. Most of the exoplanets found to date are reasonably warm, as planets that orbit closer to their stars are easier to spot. That said, the planet with the name of OGLE-2005-BLG-390Lb is a contender for a Hoth lookalike. With temperatures plummeting to -220°C, it is almost certain to be covered with ice.

3. Mustafar/COROT-7b

Obi-Wan Kenobi and Darth Vader duelling on the lava planet of Mustafar was a memorable moment in *Revenge Of The Sith*. The most likely real-life counterpart is probably COROT-7b. At the time of its discovery in 2009, it was the smallest rocky planet ever detected outside our Solar System. Due to its proximity to its parent star – orbiting it in just 20 hours – the temperature rises beyond 2,000°C, enough to melt the rock into lava.

4. Kamino/Kepler-22b

The water world of Kamino is home to Jango and Boba Fett. Planets known as 'super-Earths' might be entirely enveloped in water too, as their stronger gravity levels out mountains and volcanoes. The first terrestrial planet ever found in the habitable zone of a Sun-like star – Kepler-22b – has a strong chance of being a Kamino analogy.

5. Endor/exomoons

In *Return Of The Jedi* we enjoyed watching the Ewoks running around Endor, a forest moon. There's every reason to believe that similar moons exist in the Milky Way; in fact, some researchers think that habitable moons may outnumber habitable planets. Finding exomoons is hard, but astronomers are scouring Kepler data for them.

6. The Death Star/Mimas

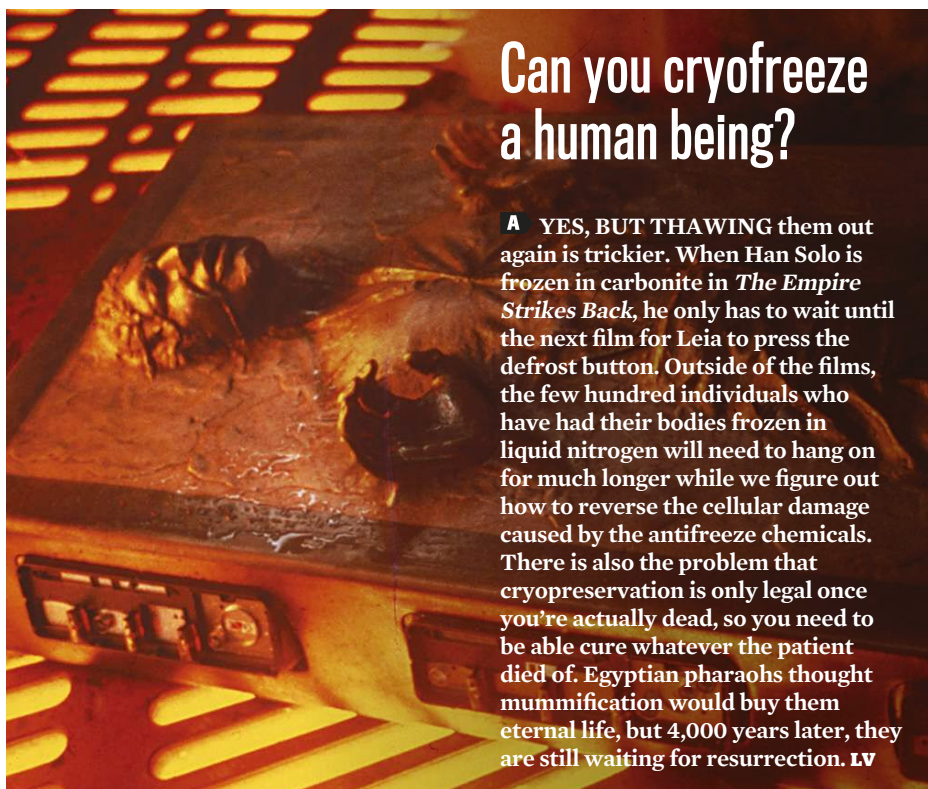
That's no moon. Except that it is. Saturn's moon Mimas looks eerily like the Death Star in *A New Hope*. Curiously, however, there is no way George Lucas could have drawn inspiration from Mimas – we didn't know it looked like that until the Voyager 1 probe flew by in 1980. The film had been released three years earlier. Astronomers are still baffled as to why the impact that caused Mimas's distinctive crater didn't blow the moon apart.

What would be the psychological effects of seeing your planet disappear?

A DEVASTATING. IMAGINE BEING a refugee displaced by war here on Earth. You see your home, your town and even your whole familiar country reduced to rubble. You might suffer post-traumatic stress, depression, anxiety, insomnia and many other mental troubles. Now imagine you are a refugee from your home planet, leaving behind everything that is familiar to

you, from the plants and animals to the cities, roads and people. Few people could survive such total loss with equanimity. It is perhaps surprising that more than 200,000 people have volunteered to join the Mars One mission, many of whom say that a slim chance of surviving for a year or so in a confined and alien world would be worth the one-way trip. Psychologists

fear they are underestimating the trauma, loneliness, boredom and fear they face. Even so, those who go will know that their home planet, Earth, still exists and they may even be able to communicate with friends and family there. When Alderaan is destroyed by the Death Star's superlaser, the surviving Alderaanian people have not even that small comfort. **SB**



Can you cryofreeze a human being?

A YES, BUT THAWING them out again is trickier. When Han Solo is frozen in carbonite in *The Empire Strikes Back*, he only has to wait until the next film for Leia to press the defrost button. Outside of the films, the few hundred individuals who have had their bodies frozen in liquid nitrogen will need to hang on for much longer while we figure out how to reverse the cellular damage caused by the antifreeze chemicals. There is also the problem that cryopreservation is only legal once you're actually dead, so you need to be able cure whatever the patient died of. Egyptian pharaohs thought mummification would buy them eternal life, but 4,000 years later, they are still waiting for resurrection. **LV**

Could a slug grow to the size of Jabba the Hutt?

A THE LARGEST LAND slug species is the black keel back slug, which grows to 20cm. Slugs don't get much bigger than that because they are cold-blooded, slow-moving, and can't gather enough food to power a larger metabolism. Land slugs have simple lungs and a multi-chambered heart, not dissimilar to early vertebrates that first climbed out of the sea. With the right food source, it's possible that molluscs could evolve to be as big as mammals. **LV**



HOW IT WORKS

BB-8

Looking like R2-D2's cooler, cuter cousin, BB-8 is set to be one of the stars of *The Force Awakens*. We peer inside the toy version of the rollerball droid to find out what makes it tick.

'Floating' head

BB-8's head is connected to its body by an array of magnets in the head and inside the sphere. The magnets are placed so that some attract each other, while others repel. This makes the head appear to float.

Gyroscope

The head stays on top of the body as it moves, meaning that the droid must 'know' which way is up. A tiny gyroscope in the main sphere is used to sense its alignment, then corrects the lower magnet array's placement to keep it in the top half of the sphere, maintaining the head position.

Omni wheels

Two omni wheels connect the droid's motor assembly to the inside of the shell, so that the sphere can roll in any direction. An omni wheel can turn forwards, backwards and sideways, thanks to spinning cylinders around its rim. The droids used for the film were less sophisticated: they included remote-controlled props, a puppet, trike versions, and even a throwable 'bowling ball'. They were all built as practical effects and then enhanced post-production. The working promotional version detailed here was made after filming, by the original effects team and robotics firm Sphero.

Motor assembly

The motor assembly, batteries and computer all sit at the base of the droid, between the wheels. The weight of these components helps to keep the droid stable. The motors respond instantaneously to input (the BB-8 toy is controlled via a Bluetooth app), driving the wheels as needed. Just don't ask it to climb up the stairs...

Accelerometer

Like the gyroscope, the accelerometer works in all directions, measuring speed and acceleration and feeding back to the computer. The computer then makes micro-adjustments to the motors, to keep the droid stable and moving in the right direction.



YOUR QUESTIONS



Stormtroopers:
hard of armour,
thick of skull

Q GABRIEL MULTEDO, BY EMAIL

What could a Stormtrooper's armour be made of?

A STORMTROOPERS' EXISTING armour is already pretty advanced, incorporating temperature controls and blast energy sinks to absorb the impact of stray blaster bolts. But the Galactic Empire might also wish to consider so-called liquid armour made of Kevlar laced with shear-thickening fluid (STF). In STF, silica nanoparticles are suspended in a liquid polymer. As the Stormtrooper goes about its business, the material remains flexible. But should some shrapnel from, say, a Rebel Alliance thermal detonator grenade hit the suit, the fragment's kinetic energy forces the silica particles together into a rigid lattice, stopping the shrapnel in its tracks. Already elite soldiers known for their strength and endurance, the Stormtroopers might also benefit from powered exoskeletons like Lockheed Martin's HULC (Human Universal Load Carrier) or China's EEAE military exoskeleton, unveiled in 2014 at a trade show. Hydraulic actuators at the wearer's joints and along the limbs would boost a Stormtrooper's running and jumping capabilities. The only problem? Iron Man got there first in a different movie! **GM**



Above: The HULC allows humans to carry heavy loads across all terrains

In Numbers

218cm

is the height of Peter Mayhew, who played Chewbacca. In comparison, Carrie Fisher (Princess Leia) is just 155cm

Above: The liquid within this vest hardens on impact



Seeing double:
Tatooine orbited
two suns

Q @RICH_141

In an infinite universe (or a quantum world), does the world of *Star Wars* exist in a galaxy far, far away?

A AN INFINITE UNIVERSE doesn't guarantee every possible combination of atoms exists somewhere. The universe we can see could be a tile that's endlessly repeated across an infinite bathroom floor, without any variation. Or it could be that the density of matter tapers off forever but never quite stops, so after a while it drops to just one proton every billion cubic light-years; the only region that is dense enough for stars and galaxies to exist is the middle part we live in.

If quantum physics allows parallel universes, and there are an infinite number of them, however, then it's entirely possible that one of them contains the galaxy depicted in *Star Wars*. But again, it's not inevitable. Imagine the roll of a die across infinite parallel universes. Every possible result will occur somewhere, including the die balancing on one of its edges. But you'll never roll a seven. Some outcomes are just impossible. **LV**



Yes it's fast, but its
commander doesn't even
know the difference
between time and distance

It turns out that
gravity on the Death
Star is pretty nifty



Q @AARONBOARDLEY

Is there a constant 'up' on all the Death Star's floors, or is the core always down?

A THE FIRST VERSION OF the Death Star was only 160km in diameter, which makes it more like a large asteroid than a moon, and too small to have any significant natural gravity. If the Death Star rotated once every nine minutes, this would be enough to generate 1g of centrifugal force at the surface, but this would point outwards. Instead, the Death Star has artificial gravity that points towards the core for the decks nearest the surface. In the central section, all the decks use a separate gravity that points down towards its south pole. **LV**

NEXT MONTH Over 20 more
of your questions answered

For more answers to the most puzzling questions, see the Q&A archive at sciencefocus.com/qanda or follow us on Twitter @sciencefocusQA

IT WOULDN'T BE
Christmas
WITHOUT
RadioTimes

ON SALE NOW



Merry Christmas, from
RadioTimes

THE FUTURE OF GADGETS

TECH HUB

EDITED BY **RUSSELL DEEKS**

THIS MONTH

BILL THOMPSON
Wanted: life
cataloguer
p81

ULTIMATE TEST
Cool winter
sports gear
p84

ON THE HORIZON

LYTRO IMMERGE

A camera for making
virtual reality worlds
lytro.com

WHEN LYTRO LAUNCHED its first Light Field camera back in 2012, enabling you to refocus pictures *after* they'd been taken, it was revolutionary – so much so that the rest of the camera industry has yet to catch up. But

Lytro isn't resting on its laurels: it's now putting its Light Field technology to use in 3D motion picture capture for VR applications – a sector of the industry that's currently booming.

Where traditional photography records the colour and intensity of light at a given point (whether on a piece of film or a CCD sensor), Light Field or 'plenoptic' photography uses an array of lenses to capture much more information about the light in a given space, including its direction. Capturing so much data is what gives cameras such as Lytro's ILLUM the ability to change the focal point and depth of a picture after it's





The Lytro Immerge would capture the real world and translate it into a virtual replica

➔ been taken. But all that additional information available about how photons are bouncing around also comes in handy for capturing 3D film footage in order to create virtual worlds.

That may seem like quite a niche application – and to a certain extent it is. No-one's suggesting that we're all going to rush out and buy Lytro's Immerge 3D video camera: it's strictly aimed at broadcasters, games production houses and other producers. But even they are being offered leasing options, because the Immerge system isn't cheap. Yet the fact that Lytro is investing so heavily in the sector underlines the increasing role that VR is likely to play in our lives.

Whether you're wearing dedicated hardware like Oculus Rift to play games, or using a smartphone-based solution like Google Cardboard to experience cutting-edge 'virtual journalism' (see, for instance, recent experiments by *The New York Times*), the fact is that after years of hyperbole, false starts and disappointment, virtual and augmented reality are soon going to be commonplace. This will create the impetus to find new ways to make the highest quality content – which is where Immerge comes in.

The Immerge system consists of a Light Field camera array and a portable server, plus a suite of editing and playback software. By capturing data from all directions, the camera enables the server and its firmware to generate virtual views

from any point, facing in any direction. This, says Lytro, means content producers can create "a breakthrough sense of presence, with six degrees of freedom".

Lytro's Chief Product Officer Ariel Braunstein explains: "It's currently impossible to recreate multiple virtual views in a scene with a single capture from existing 2D video technology, which does not provide enough depth information. Many production houses are developing their own VR equipment and software simply out of necessity, in order to deliver their vision. We believe that Light Field technology solves many issues that face VR content creators right now.

"We believe that by helping to alleviate these pain points," he continues, "we will hopefully help VR storytellers create the kind of immersive experiences that will ultimately lead to wider consumption."

Light Field imaging isn't the only way to create immersive video, of course – there are almost as many ways to represent a cat from multiple viewpoints with realistic horizontal and vertical parallax as there are to skin one! But the arrival of the Lytro Immerge is another sign that the worlds around us – the real and the virtual ones – are about to get a whole lot closer.

RUSSELL DEEKS is a freelance technology journalist, and Contributing Editor of Focus

TECHOMETER

WHAT'S HOT

WAX CYLINDERS

Not the cylinders themselves – they were edged out by new-fangled 'records' around the time of WWI. Rather, it's the music stored on them that's making a comeback. A team at University of California, Santa Barbara has been busy digitising over 10,000 recordings from the 19th and 20th Centuries, which you can hear and download at cylinders.library.ucsb.edu



WHAT'S HOT

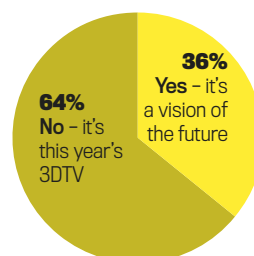
BETAMAX

Sony has announced that in March 2016, it will discontinue production of Betamax cassettes. Despite VHS emerging as the dominant video format by the mid-1980s, Sony carried on making Betamax equipment right up until 2002, and it's been quietly supplying users with new tape all this while. But March will see the format's 41-year run finally coming to an end.



READER POLL

Will virtual reality take the world by storm?



THE NEXT BIG THING

DIGITAL ARCHAEOLOGY

Are we becoming buried under mountains of data?

AS PART OF my job, I get to give a lot of talks at conferences. I enjoy it a lot, partly because I like to meet new people, partly because it provides me with an opportunity to travel, but mostly because I've always found that the best way to test out your ideas is by saying them out loud in front of a bunch of sceptical listeners.

And I like to use my own photos when I can, because they make the whole thing a lot more real. In fact, I'm writing this in a cafe in Bern where I've been taking photos that I'll use in a talk today.

Unfortunately I can't find a photograph I'd really like to use, of some young people playing a PlayStation game in Nairobi's Kibera slum back in 2009. It should be somewhere in my photos, but it seems to have moved, and I never got round to tagging it or saving it with a sensible file name, so Spotlight can't find it. I have used it in other presentations, but I'm not sure which ones and it would mean trawling through a lot of files that I keep in the cloud these days because my laptop doesn't have much disk space.

This is a minor problem for me, but it's a growing one for our society as a whole. As each of us generates more and more digital data, spread across devices we own and a bewildering array of online services or cloud storage platforms, we're going to find it harder to connect with our memories. And we're going to leave our kids and ancestors with no real record of who we were or how we lived our lives.

Some media are better than others. With email and documents, a dumb text search will generally give you useful results. But all those recordings of interviews and talks I've saved might as well be deleted given how likely I am to transcribe or use them again.

There is an opportunity here. We're already seeing 'digital archaeology' emerge as an academic discipline, as we look to historians and biographers to make sense of the data detritus we leave behind. And there are new tools that will trawl your images, videos and sound files and do a half-decent job of tagging them, like Google Photos or the BBC's Comma toolset. Yet the nuances of classification seem likely to



Google's data centres hold a lot of the world's data, but good luck sorting through it...

resist algorithmic interference for some time, if only because the range of reasons a person might want to find a specific item is effectively unlimited.

Once upon a time a wealthy person might have advertised for a 'corresponding secretary' to help deal with letters and invitations – perhaps there's a new career path emerging for the digitally-minded young people coding on the Raspberry Pi or eagerly awaiting the delivery of the

first batch of BBC micro:bits to their school. Then they can help the older generation tag and organise their digital photographs, blogposts and Vines, and ensure that we don't end up bequeathing the world a pile of useless bits.



BILL THOMPSON contributes to news.bbc.co.uk and the BBC World Service

FROM THE LAB EM-SENSING

WHAT'S 'EM-SENSING'?

It's a new technology, developed by Disney and Carnegie Mellon University, that enables a wearable device to know what objects – for instance a keyboard or power tool – you're holding.

HOW DOES IT WORK?

All electrical or electromechanical objects emit small amounts of

electromagnetic (EM) 'noise' that propagates harmlessly through your body when you touch them. These signals can be used to identify objects.

WHY IS IT USEFUL?

The idea is that a smartwatch or other wearable device with EM-sensing would know what you're doing and then feed you data that's specific to that task: local

maps if you're driving, for example, or a timer if you're brushing your teeth. The system could also be used to log you into your computer without using a password.

SO WHEN'S IT HAPPENING?

Sadly there are no plans for actual products yet – the research is still at the 'proof of concept' stage.



The EM-sensing device can easily discriminate between various objects

GYROSCOPE.COM

The **Super Precision Gyroscope** has been designed and built to the highest precision from the very start, made from solid brass with a light-weight aluminium frame. Carefully chosen stainless-steel miniature ball bearings allow it to run smoothly and almost silently. The gyroscope operates at over **12,000 rpm** using the provided **electric motor** and battery pack. The gyroscope comes with a number of attachments allowing numerous configurations to perform scientific, educational or simply mesmerising experiments. The brass disk is machined to **microns precision**, ensuring the disk is incredibly symmetrical and well balanced. The disk is then **computer balanced** to an impressive 250th of a gram accuracy! Thus giving the gyroscope a highly balanced, super smooth feel, longer spin and even quieter operation. Visit www.gyroscope.com for details and to see our other products.



This beautifully made small sports car AS4 is a homage to the first Mercedes vehicle. It is powered by a Stirling Engine with its fuel source being a small alcohol burner. Made of 100 parts. Ready to run.



These miniature 3cc V-Twin combustion engines run off butane or propane gas. They are small enough to run on your desk and have an awesome v-twin sound. Just turn the valve and flick the flywheel to get it started.



This Vulcan stove fan is driven using Stirling engine technology using just the heat from a stove. It requires no external power source such as batteries or AC power. The fan circulates the stove's warmth quietly, efficiently and inexpensively.



Newly invented, this tractor beam magnet contains a number of magnets in a special arrangement. The special arrangement creates a unique magnetic field that can hold another magnet a fixed distance away.



This is a Hero Steam turbine. Syringe in some water. Fill the burner with methylated spirits and light it. Moments later you have a steam turbine running. Two tiny jets of steam coming out of the side of the brass ball spins it up to 2500rpm.



These are highly polished solid metal flip over tops. They have a chrome like finish and are excellently machined. Simply spin it as normal and watch it suddenly flip over and then continue to spin upside-down.



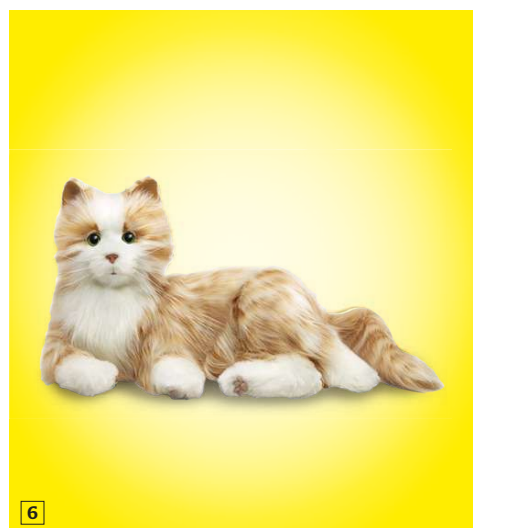
Ferrofluid is a runny fluid that is magnetic. Hold a magnet to it and watch how it reacts. Some of the shapes you are can create are mesmerizing.

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APPLIANCES OF SCIENCE

1 BACK ON BLACKBERRY

No need to check the date... we really *are* shouting about a new BlackBerry in 2015! The PRIV is the embattled mobile-maker's first phone to run on Android, and its name reflects the emphasis placed on security. With an 18MP camera, 5.4-inch screen, 4K video camera and up to 2TB of storage, the full range of Android apps plus BlackBerry's slide-out keyboard, could a BlackBerry once more become 'the mobile for business'?

BlackBerry PRIV
£559, blackberry.com

2 CAN YOU SEE MY AURA?

At time of writing, this latest virtual reality headset had smashed its Kickstarter target with three weeks to go, and the first units will ship in February. Unlike Google Cardboard or Samsung Gear, it's a self-contained unit and doesn't require you to strap your smartphone to your face; unlike Oculus Rift or HTC Vive, it's also completely wireless. It runs on Android, and comes complete with a Bluetooth controller.

AuraVisor
£300, auravisor.com

3 ROOM FOR A VIEW?

As smartphones get larger displays, some have been predicting the death of the tablet. In response, Samsung's gone for the nuclear option, serving up this 18.4-inch, Full HD Android tablet with an octacore 1.6GHz chip, Wi-Fi and 32GB of storage. The specs are a tad underwhelming, but if we had a choice of watching *The Force Awakens* on a Note 3 or this, we know which we'd choose!

Samsung Galaxy View
\$599 (£400 approx),
samsung.com

4 SMUT-FREE SURFBOX

Torch is a router built with families in mind. As well as all the built-in porn-busting filters you'd expect – which are user-customisable – it can be easily set up via a smartphone app (iOS only for now) to impose 'time-outs' and 'bedtime', limiting the time young 'uns spend online, as well as providing parents with a complete browsing history that can't be erased or circumvented by 'private browsing'.

Torch router
\$160 (£106 approx),
mytorch.com

5 BOOKSHELF BLUETOOTH

Bluetooth speakers come in many shapes and sizes these days, but one form factor that's surprisingly rare in Bluetoothland is the traditional 'bookshelf' speaker. That's the gap in the market that Thonet & Vander hopes to plug with its Hoch BT airshifters, which boast a one-inch silk tweeter and 5.25-inch Aramid fibre woofer, and pump out 35W per channel. Don't expect lashings of bass, though.

Thonet & Vander Hoch BT
£130, thonet-vander.com

6 FUTURE FELINE

Designed to combat loneliness in the elderly, Companion Pet Cat is the first in a new line of robot pets from Hasbro. Equipped with motion and light sensors, realistic fur and, ahem, VibraPurr technology, it responds to being petted by purring, but will go to sleep if left alone for more than a few minutes. Whether it'll also wake you up at 5am by jumping on your face is still TBC.

Companion Pet Cat
\$100 (£66 approx),
joyforall.com

ULTIMATE TEST

WINTER SPORTS GADGETS

Whether you're seeking instant data, filming your Chamonix sojourn or simply want to defy the elements, **James Witts** explores the latest high-tech hardware for skiing and snowboarding this season



POC FORNIX COMMUNICATION

£200, pocsports.com

In many ways, the Poc Fornix is similar to most other winter helmets out there. The Swedish brand moulds together aramid strings and a foam liner to create a helmet that'll not only protect you from the daily tumble, but do so at a relatively lightweight 420g. Poc also keeps venting to a minimum, to retain warmth without turning your goggles into a sauna and the slopes into a sweat fest. But it's the addition of the lowercase 'b' that'll appeal to the helmet-bangers out there, as a cosy neckroll hides integrated Beats by Dr Dre headphones. It comes with a remote control so, as Poc says, you can "take calls, switch tunes and adjust volume right from the cord".

CELESTRON ELEMENTS FIRECEL

£30, celestron.com

Darkness is rolling in, your hands are frozen and your phone's out of juice: three less than ideal situations when you're up a mountain. That's where this nifty device comes in. Celestron's three-in-one tool features a hand-warmer, multi-mode flashlight and power supply. For up to 12 hours, you can switch between heating one side or two, depending on whether it's in your pocket or clenched in your hand. The rechargeable lithium ion battery fully revives most phones twice, while the torch integrates red and white LEDs and has five modes. A sleek aluminium shell adds protection while keeping weight down to a slimline 100g.





KJUS FORMULA DLX JACKET

£1,120, snowandrock.com

Sashay down the slopes in style with this uber-expensive but equally technologically advanced jacket from Switzerland. For the asking price, you might expect a myriad of wearable technologies; if so, you'll be disappointed. Instead, the lofty price derives from a collection of cutting-edge fabrics that'll keep you warm, give you unparalleled freedom of movement and deflect rain with ease. Key to the DLX's innovative approach is a material called Dermizax, which is both waterproof and windproof, while still breathable enough to ensure you don't 'boil in the bag'. It's also mighty comfortable: it'll move with you, rather than fighting you, thanks to Dermizax having elasticity of more than 200 per cent. The jacket also boasts a detachable hood that can be adjusted with one hand.



BCA TRACKER 3

£300, snowandrock.com

Here's one product you hopefully won't ever need – an avalanche transceiver. Billed as the thinnest multi-antenna transceiver available, the Tracker 3 includes a host of search features, including the ability to track multiple targets if more than one person is submerged, and a digital display showing distance and direction to the unfortunate target. It has a maximum search range of 50m and doubles as a warning signal, so it will transmit a beacon to search parties if ever you're overcome by an avalanche. Three AAA batteries supply the technical life-force, peaking at 200 hours in 'transmit' mode and a minimum of one hour in 'search' mode.



OAKLEY AIRWAVE

£520, uk.oakley.com

In the Airwave, Oakley has employed heads-up display (HUD) technology that was developed for fighter pilots. As you conquer every slope, a number of measurements are projected onto the lenses, including average and max speed, altitude, temperature, jump analytics and Trip Viewer, which provides stats for your total ride. Over 200 built-in maps give you pinpoint navigation, while the 'buddy tracking' tool tells you exactly how far ahead of/behind your compadres you are. It can link via Bluetooth to iOS or Android devices for viewing phone calls and text messages, while a music control enables you to scroll through your smartphone playlist.



SUUNTO AMBIT3 PEAK SAPPHIRE

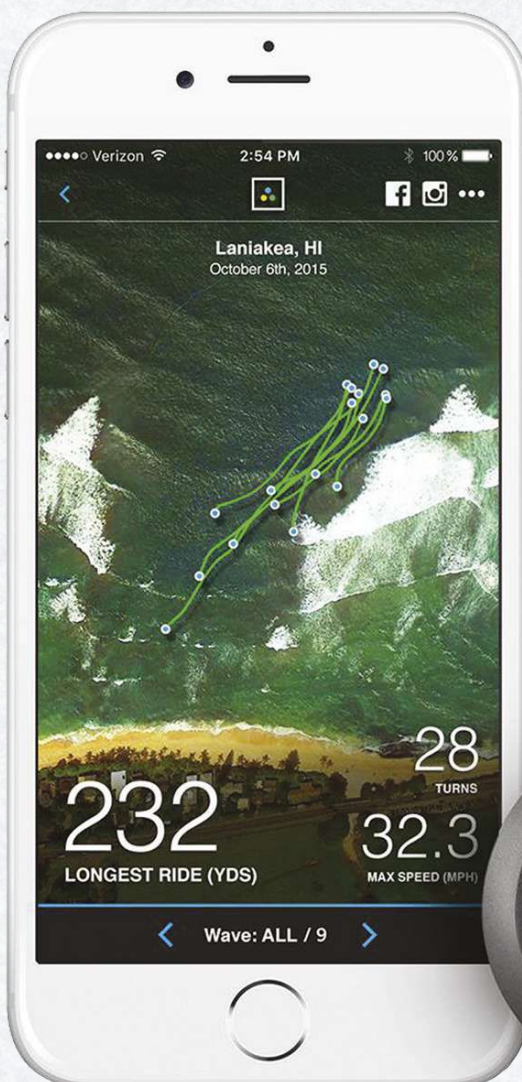
£405, suunto.com

Suunto's Ambit 3 Peak is one of the most advanced adventure watches on the market, providing GPS data such as speed, pace and distance; an altimeter; compass; notifications; and temperature. It also gives sunrise and sunset data, so you can monitor how much time you've got left on the slopes, while a comfortable chest strap offers heart-rate capability for monitoring intensity of effort. With GPS on, the battery life is an impressive 30 hours, and if the worst happens and you find yourself lost, a useful 'track-back' feature will return you safely to your chalet. The feature list reaches epic proportions via Suunto's Movescount app, where you can even create a movie of your efforts, complete with 3D maps, images and key metrics.

TRACE

\$200 (£133 approx), traceup.com

Trace entered production thanks to over a thousand Kickstarter backers pledging a total of \$161,260, each of them spotting the gap in the market to analyse and improve technique on the slopes. The premise is simple: stick the lightweight Trace to your skis or snowboard, give it 24 hours for the mount to fully adhere and away you go. GPS sensors and accelerometers collect data on vertical distance, average speed, airtime and the number of jumps you've completed, which you can assess in more detail on your smartphone or laptop via the Trace Snow app. Rather neatly, you can sync it to your GoPro footage and overlay the stats. It even hints at AI by auto-editing your GoPro footage to cut out the boring bits.





PANASONIC A1

£350, panasonic.com

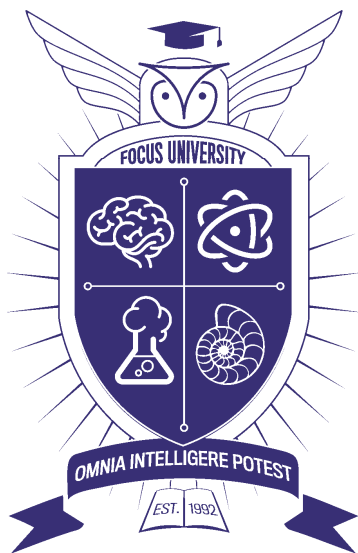
The A1 is Panasonic's first 4K action camera, following in the 4K footsteps of GoPro's Hero 3 Black Edition. However, unlike the GoPro, the unit's split into two sections. At one end of a cord are the fixed lens, sensor and microphone; at the other sits a recording system featuring a 1.5-inch screen and control buttons including a joystick for scrolling through the menu. A neat multi-mount clips the camera onto your goggles – though other mounts are available if you want to take it running, or simply shoot on a tripod – and built-in Wi-Fi means you can swiftly transfer your award-winning footage onto your smartphone or computer later.

BEARTEK SNOW GLOVES

\$250/\$380 (£165/£250 approx), beartekgloves.com

Fancy descending with the speed of Alberto Tomba but having the power of communication at your fingertips? Now you can, with this high-tech set of snow gloves. Aesthetically they're quite traditional, with weatherproof goatskin leather insulating your digits while keeping them dry. But slip a phone or camera module – you can buy them with one module or both – into the wrist area and you transform your gloves into a 'handy' audio-visual device. Sync with your phone via Bluetooth and each finger performs a function. With the camera module, which works with GoPro cameras only, that might mean taking a single shot or video; with the phone module it could be answering or declining a call. The modules are also designed to receive software updates.





UNDERSTAND THE ORIGIN OF LIFE IN 10 MINUTES

There are millions of species alive on Earth today.
But how did life get started in the first place?
Tom Ireland travels back through four billion
years of history to find out

The origin of life - how long ago was that?

Around four billion years ago, when the Earth was still partially molten and under heavy bombardment from meteors, the very first life-like systems appeared. Somehow, chemicals developed life-like properties – using matter and energy from the hellish environment to make more of themselves. Origin of life researchers are still trying to work out exactly how, during this period, chemistry suddenly became biology.

Once basic biological systems formed, life never looked back, evolving into the two enormously diverse groups of microbes now known as bacteria and archaea. A merger between two of these ancient cell types, billions of years later, is thought to have given rise to more complex, multicellular organisms – including us, and all the plants, fungi and animals that ever lived.

How exactly did life begin?

Unfortunately, there is no consensus or standard model to explain how life started on Earth. However, most theories are based on the idea that at some point early in the planet's history, chemicals developed characteristics that are found in all living cells today – the ability to self-replicate, for example, or to produce other useful biological molecules.

Once such biological characteristics emerged, a sort of 'chemical evolution' was set in motion: chemicals made copies of themselves, some emerging with variations that made them either more or less efficient, or helped them cooperate with others. The variants that worked best made more copies of themselves, while the others were outcompeted for raw materials.

Over billions of generations, more complex variations emerged, with the basic molecular processes of life enclosed within a membrane. These cell-like structures were essentially the first microbial cells, from which all life evolved.

More fanciful theories suggest that life on Earth was 'seeded' by ancient microbes falling from space.



Stromatolites, like these in Australia, formed from ancient microbes up to 3.5 billion years ago

What is the earliest evidence of life on Earth?

The oldest cells ever found are fossilised in rocks dated to around 3 to 3.4 billion years ago. These early cells look a bit like cyanobacteria, which is still abundant today. They were likely to have been thermophiles, meaning they liked hot places, and autotrophs, meaning they made their own complex organic compounds from simple chemicals. Further back in time, there must have been an older type of organism from which these cells evolved.

Other evidence of ancient life can be seen in the form of stromatolites – rocky structures formed from the gritty deposits of vast sheets of ancient microbes floating in the sea. Some of these, found in Western Australia, are thought to be up to 3.5 billion years old, but little is known about the organisms that made them.

The oldest evidence of life on Earth is mysterious traces of a certain isotope of carbon, which researchers think must have been produced by a living organism. Some of this graphite, also found in Western Australia, is thought to have formed around 4.1 billion years ago. This is almost as old as the oldest rocks ever found on Earth, suggesting life may have appeared surprisingly soon after the planet formed.

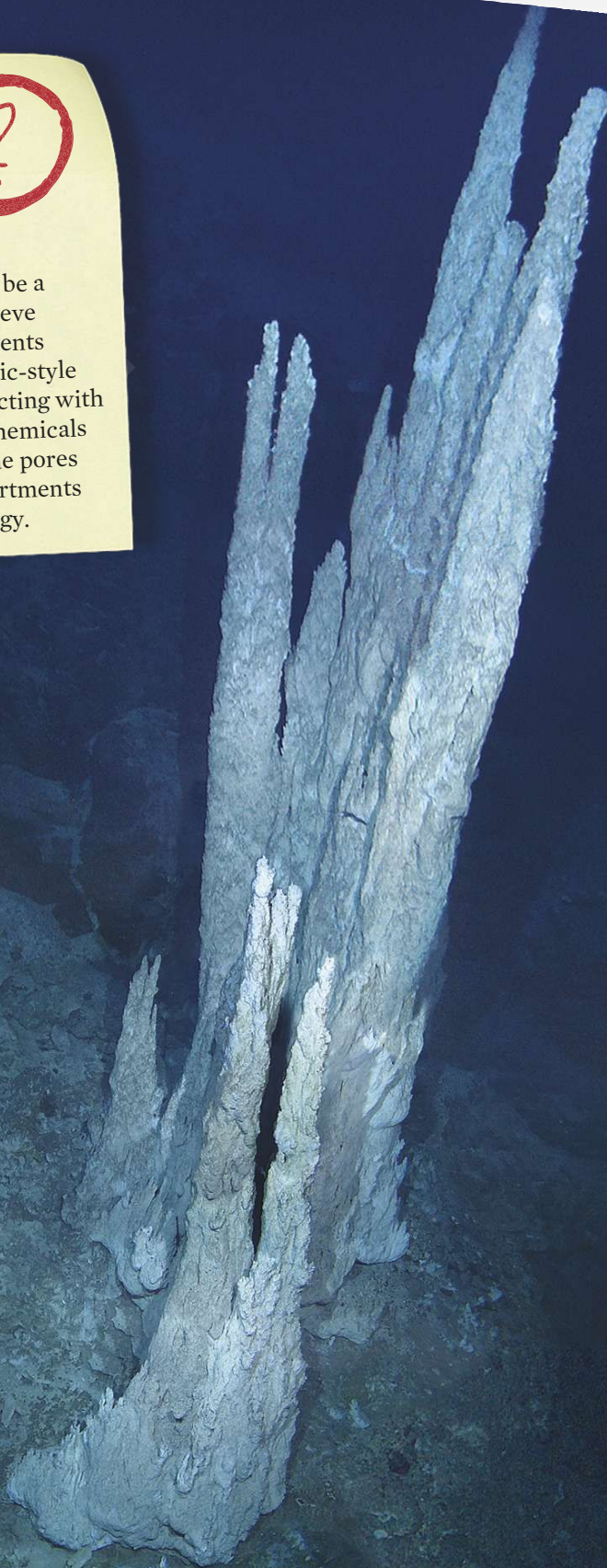
But what left these tantalising traces of life? Here the trail goes cold. The theory of how life began,



What
is this

?

Our most ancient ancestor could be a porous rock. Some scientists believe conditions in deep-sea alkaline vents would have encouraged metabolic-style reactions. Alkaline minerals, reacting with seawater, create concentrated chemicals within tiny pores in the rock. The pores could have acted like the compartments in living cells that generate energy.



TIMELINE

First living organisms appear. Specks of graphite, thought to be produced by early life, have been dated to 4.1 billion years ago – as old as the oldest rocks.



4.5-3.8 billion YEARS AGO

3-3.5 billion YEARS AGO



The oldest evidence of actual microbial cells dates back to around three billion years ago. These were similar to cyanobacteria (pictured). The last known common ancestor of all life on Earth lived in this period, just before cells split into two main types: bacteria and archaea.

Evidence of oxygen in the atmosphere suggests an abundance of oxygen-producing, photosynthetic organisms. The first eukaryotic cells appear, thought to be the result of one cell enslaving another as an energy source.

2-2.5 billion YEARS AGO

580 MILLION YEARS AGO



Multicellular life on Earth starts flourishing. The relatively short period during which many animals first appeared is known as the 'Cambrian explosion'. Pictured are some creatures that lived in this period.

The first humans or human-like beings appear on Earth.

2-3 MILLION YEARS AGO



PRESENT DAY

There are estimated to be at least 10 million species of organism living on Earth today, but the vast majority are still unknown to scientists. The human population is over seven billion, and mankind is now exploring space for signs of other life.



→ from the innate chemistry of early Earth to those early cells, is a puzzle that remains unsolved.

Why are there still so many unanswered questions?

As well as there being no clear evidence to examine, at the heart of the problem is a paradox. To make the complex biological molecules required for life normally requires other biological molecules. How could any of these intricate molecules be made when biological systems did not exist to make them?

DNA, for example, cannot form by some sort of chemical accident – to make it requires specific enzymes. But to make those enzymes requires the precise instructions carried by DNA.

There are other fundamental problems too – even if complex organic molecules like enzymes and DNA did arise spontaneously, how and why did they begin to cooperate as a system? And how did early life manage to create large organic molecules without the complex energy systems that drive the process in modern cells?

What is 'primordial soup'?

Life is often said to have started spontaneously in a 'primordial soup' – a sort of chemical stock formed in the pools and puddles of early Earth. Charles Darwin once wrote a letter to a friend in which he speculated whether life could have originated in "some warm little pond somewhere", and scientists such as JBS Haldane and Alexander Oparin (who coined the phrase 'primordial soup') developed the theory in the 1920s.

Both said that various chemical compounds could accumulate and become concentrated in locations where hydration and drying regularly occur, such as shorelines, rocky pools or oceanic vents. Cycles of hydration and drying, plus energy from magma, ultraviolet light or lightning, could be conducive to the production of complex organic molecules, they said. Finally, at some point, fat-like molecules could have formed an 'oily film' on the soup that enclosed important molecules within bubbles, forming the first cell-like units.

For decades, however, there was very little evidence to support this idea. It appeared that the essential molecules of life – proteins, fat-based cell membranes, and DNA – were only found in living organisms and could not form without the molecular machinery contained inside cells.

In 1952 a young scientist named Stanley Miller put water, methane, hydrogen and ammonia together in some lab equipment (see 'Life in the lab'), and frazzled it with thousands of volts to emulate the fierce electrical storms that would have been a feature of Earth's turbulent atmosphere at the time life first appeared.

Within a few days, the mixture had turned into a rich, brown mix of chemicals, and analysis found that amino acids – the building blocks of proteins – had formed spontaneously.

The experiment was key in supporting the view that life could arise from simple chemicals on the surface of the Earth. Modern analysis has since found that all 22 of the essential amino acids required for life can be made like this. Scientists have also since made other important biological chemicals in similar ways, such as nucleotides, the building blocks of DNA.

So did life form in the primordial soup? Well, this approach only gets us so far. Even with a 'soup' stocked with the ingredients of life, such as amino acids and nucleotides, it's still enormously difficult to get these ingredients to form very complex biochemicals such as proteins or DNA. And it's even more difficult to make versions of those molecules with meaningful biological functions.

Where else could life have formed?

Another theory gaining credibility is the idea that life began in deep-sea hydrothermal vents. At the time of life's origin, the seawater was acidic and positively charged. In contrast, the vents ejected negatively charged, alkaline substances.

These fissures in the Earth's crust, where alkaline minerals reacted with acidic seawater, created tiny pores in rocks, which appear to concentrate chemicals produced by other reactions in the vent.

Iron- and sulphur-based minerals

in the vents could have helped catalyse reactions, just like iron- and sulphur-based proteins do in modern cells.

Today, such vents often host complex microbial communities, fuelled by the chemicals dissolved in the vent fluids.

The most exciting aspect of this theory, however, is the complex chemistry occurring between the inside and the outside of the microscopic pores. This could create what is known as a 'proton gradient' – an absolutely key part of the way all organisms store energy and use it to build complex molecules.

The final stage in the theory again involves the production of fatty molecules, which can spontaneously form bubble-like, cell-like spheres. Having been produced in the chemical froth, some of these bubbles could have enclosed self-replicating sets of molecules – forming the very first organic protocells.

Could life have come from space?

The idea that life originated in space, known as panspermia, is not as wacky as it sounds. Scientists have found lots of unexpectedly complex molecules, such as amino acids or small components of DNA, nestled on comets or meteorites that have crashed to Earth.

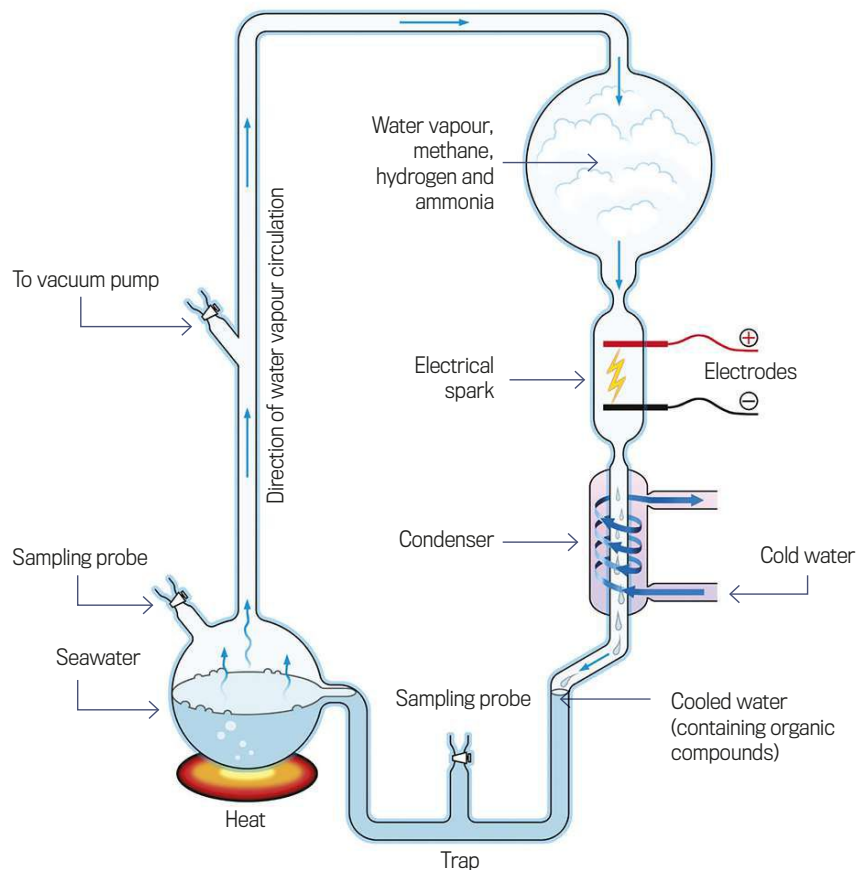
Most scientists say that these chemicals, at best, simply 'stocked the soup'. There is no evidence that cells or more complex biological molecules, such as protein or DNA, have travelled to Earth from space.

So what was the first biological molecule?

The holy grail of origin-of-life research is understanding which

LIFE IN THE LAB

Scientist Stanley Miller combined seawater and various gases together to replicate the ocean and the atmosphere. He introduced electricity to simulate a lightning storm. The process generated amino acids – the building blocks for life.



JARGON BUSTER

ABIOTENESIS

The technical term for life originating from non-living matter such as simple organic chemicals. The opposite, biogenesis, means living matter arising from other living matter, which is how life on Earth proliferated once it started.

RNA WORLD

RNA is like a single-stranded version of DNA and performs many important functions in all living cells. Scientists have shown that RNA can spontaneously form a self-replicating molecule, suggesting the Earth was once populated by simple self-replicating RNA forms.

PROTON GRADIENT

Cells can only function properly with energy created by complex metabolic reactions, which generate a difference in chemical charges in different parts of the cell. This is known as a proton gradient. Working out how it could occur spontaneously is a key part of establishing how early life functioned.

LUCA

The Last Universal Common Ancestor is the ancient organism from which all life on Earth is thought to have evolved. Although scientists have a good idea of what LUCA was like, it is a largely theoretical organism. LUCA is likely to have lived around 3.5 billion years ago, just before cells split into two main types: bacteria and archaea.

PANSPERMIA

The idea that life evolved after travelling to Earth from space.

→ chemicals developed life-like properties first and how they began to work together.

The fact that DNA carries the instructions for life suggests it was central to early life. But researchers are increasingly focused on another molecule, RNA, as potentially the first chemical to come to life.

RNA is similar in structure to DNA and performs lots of key functions in cells, from making proteins to translating and communicating the genetic code. 'RNA world' is the name given to the theory that before DNA, self-replicating RNA units began to proliferate, and evolved complexity.

Researchers making random sequences of RNA have found that some can form complex shapes, which help them perform various functions, such as acting as a catalyst for the production of other molecules.

Scientists have managed to create an RNA molecule that helps to create more of itself. This 'protogene', known as R3C, lends exciting support to the idea that chemicals can develop life-like properties such as self-replication.

Other theories suggest that life began with a much simpler version

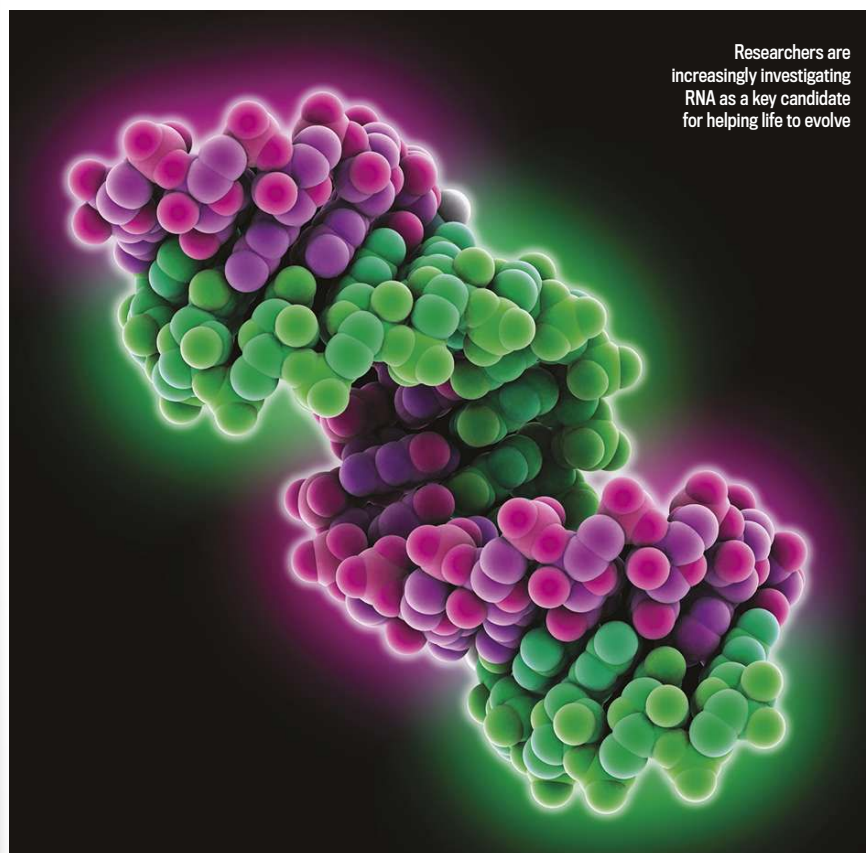
of DNA and RNA – one that was easier to form from the chemicals of early Earth. This then evolved into the amazingly robust and efficient information-carrying molecules that we see today.

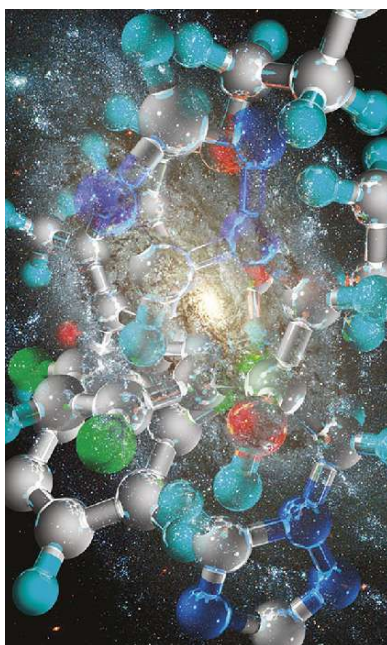
Prof Nicholas Hud, from the NASA-funded Centre for Chemical Evolution in Atlanta, believes there may have been several biological molecules coexisting at one point, and 'life' as we know it started when they began to cooperate.

"I don't subscribe to the view that there was one first self-replicating molecule," says Hud. "I believe we are descendants of the polymers that started to work together. Four types of polymer essentially form most of the metabolism of life: lipid membranes, polysaccharides [sugars], proteins and nucleic acids. These are the survivors of perhaps many different polymers."

Are there other theories?

There are dozens more theories, some of which are subtly different versions of the ones above, some of





Computer visualisation of biomolecules in the Universe

which are more left field. Many are based around conditions that might have helped concentrate important biochemicals and protect them from degradation, such as the 'clay theory' – which suggests crystals in clay could have helped arrange organic molecules into organised patterns.

Others attempt to deduce the order in which the molecules of life formed and began to cooperate. One example is the 'lipid world' theory, which suggests that membrane-like bubbles of fatty molecules were the first step towards cellular life. Although these wouldn't be information carrying units, like RNA or DNA, they may have been able to produce more of themselves and RNA might then have formed more easily within them.

Will we ever find a satisfactory answer?

Scientists working on this problem – biologists, chemists, geologists, astronomers – still disagree on the fundamentals. Speaking to origin-of-life researchers at times sounds like they are moving further away from a consensus, rather than closer.

Dr Nick Lane, a biochemist and author of the origin-of-life book *The Vital Question*, says the problem is even harder to solve than those posed by theoretical physics: "We are not even in the position of the physicists, where everyone at least agreed what

the question was and could build a huge machine like CERN to look for the answer. We are still miles away from that agreement."

However, despite the lack of a unifying theory, many scientists remain confident that a satisfactory solution is achievable. Increasingly, scientists are using computer modelling to investigate how certain mixtures of molecules might behave over time – an advance which could help speed up progress in this area. "I don't think I'm that far away..." says Lane, semi-seriously.

"The key message is that the nuts and bolts of all life is almost identical," says Matthew Powner, a chemist studying the origin of life at University College London. "The difference between us and a tree seems obvious, but people often don't understand how similar the biochemistry that it's all built from is, using very few chemical species. Eight nucleotides, 20 amino acids and a few lipids, and you don't need much else."

The overall solution may not have been solved, but each life-like molecule that emerges from a lab is another piece of the puzzle found. As broadcaster and geneticist Adam Rutherford concludes in his book *Creation: The Origin Of Life*, "That first time had millions of years, whereas scientists have made these

EXPLAIN IT TO A FRIEND

1. IT IS A LONG STORY

All life on Earth evolved from ancient, simple cells. These cells formed around 3.5 billion years ago after chemicals developed certain biological properties, such as the ability to self-replicate or cooperate with other molecules.

2. CHEMISTRY BECAME BIOLOGY

There are many competing theories on which were the first biological chemicals and how they formed. It seems likely to have happened over many millions of years of chemical reactions, assisted by catalysts such as UV light, lightning, or deep-sea vents. Some believe that key chemicals fell to Earth from space.

3. THE STAGE WAS SET FOR EVOLUTION

As soon as a chemical mixture could self-replicate, self-assemble and produce energy, the process of evolution began. Each generation produced new versions, and those with advantageous features survived and made copies of themselves.

replicators in a decade ... in all origin of life studies it is important to remember that we know the answer: Life is the answer. The question is finding a believable route to get there." ■

TOM IRELAND is a journalist and managing editor at the Royal Society of Biology

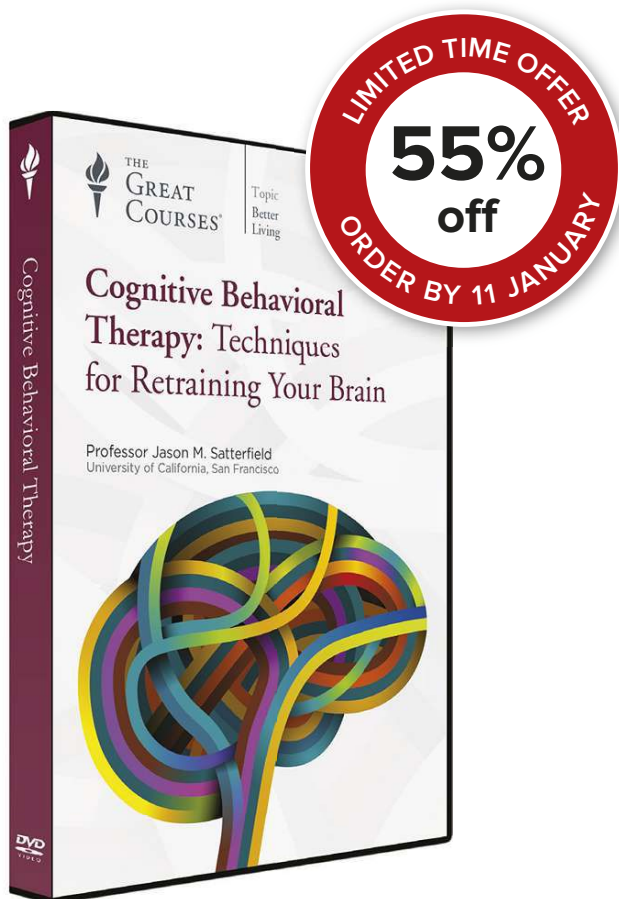
DISCOVER MORE!



Listen to an episode of *The Infinite Monkey Cage* on the origins of life: bbc.in/KEsSpt

Life may have started 4.1bn years ago, not long after the Earth formed. But how did it begin? It's one of science's greatest questions.

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PICK OF THE MONTH



The Royal Institution Christmas Lectures

→ WHILE TIM PEAKE scoffs his mince pies in space, the rest of us can settle down in front of the TV this Christmas for the next best thing. This year's Royal Institution Christmas Lectures explore the perils of space travel – a journey that will take us from Earth to Low Earth Orbit and beyond.

The three lectures, titled *How To Survive In Space*, will be presented by Kevin Fong – a medical doctor with a special interest in extreme environments. Currently working as a Consultant Anaesthetist at University College London Hospitals, he previously completed space medical training in the US.

"If you define how extreme an environment is by the time that a human can survive unsupported, then space is the most austere of all," says Fong. "This environment doesn't want to support life even for a few seconds."

Living in space is fraught with danger, but the riskiest part of a mission arguably begins on Earth. Strapped to the top of a Soyuz rocket, Tim Peake will take just 8.5 minutes to reach Low Earth Orbit – probably the most perilous few minutes of his life. In the first lecture, Fong will trace Tim's journey to the International Space Station, explaining the science

and engineering that takes humans into space. And once he makes it to the ISS, the hard work is far from over. In lecture two, Kevin investigates how astronauts are kept alive in the oxygen-devoid, radiation-riddled environment of space. Finally, the third lecture looks to the future. At 400,000km from Earth, the furthest humans have travelled is the Moon – a mere trip to the shops in cosmic terms. Fong finds out how science will take humans to Mars and beyond, out into the blackness of space.

Who knows, maybe the first person to set foot on Mars will be sitting in the audience. "Life is about exploration," says Fong. "For those who choose a life of science or technology or medicine, this is just the beginning of their adventure."

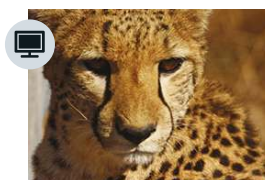
So, knowing all the risks involved, would Fong go into space himself? "In a heartbeat," he says. "If someone would offer me a ticket."

JAMES LLOYD



Watch the lectures on BBC Four over the festive period. Check radiotimes.com for full details.

DON'T MISS!



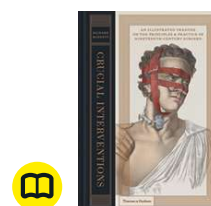
Big Cats

Discover your pet cat's amazing wild lineage, and its place in the most successful family of predators on Earth. **p97**



Destination Space

A new exhibition at Newcastle's Life Science Centre about the perils of space exploration. **p98**



Science books Xmas special

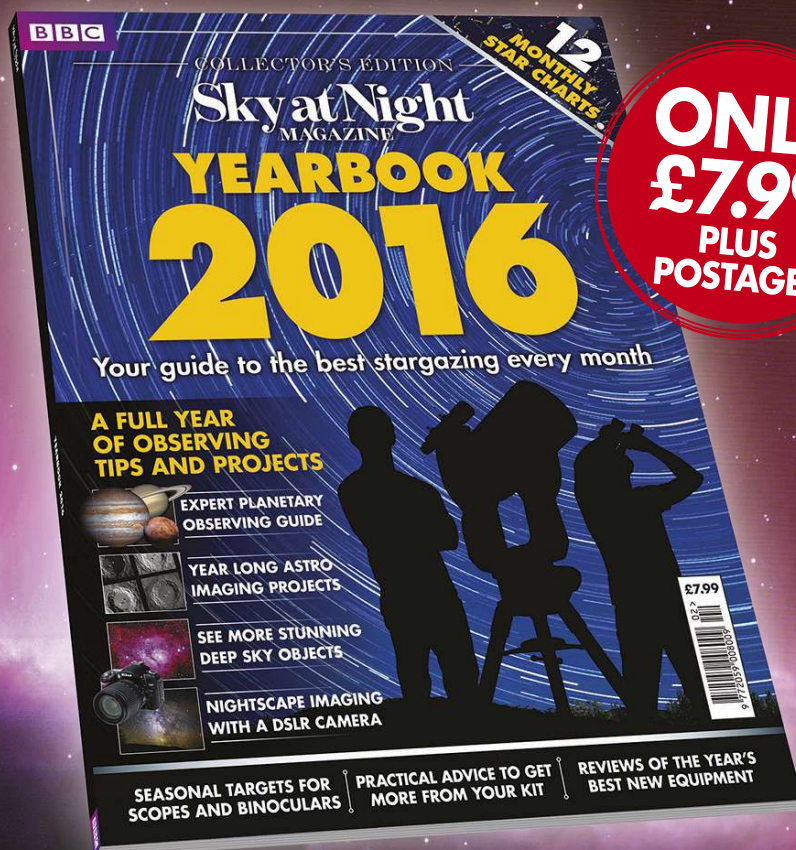
Our pick of the best stocking fillers for the science-loving bookworm in your life. **p99**

**SPECIAL
EDITION**

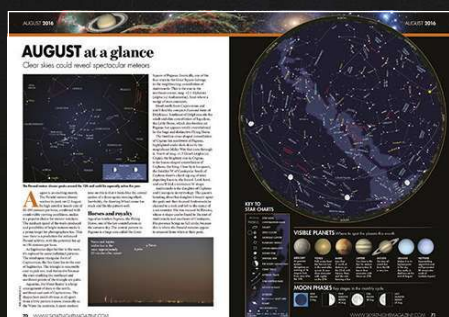
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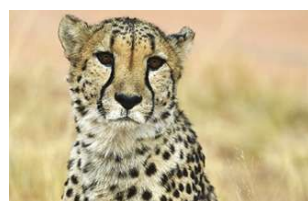
TV & ONLINE
WITH JAMES LLOYD

DECEMBER

Big Cats: An Amazing Animal Family

Sky 1, exact date and time TBC

The cat purring away on your lap belongs to a long and impressive dynasty. From lions and tigers to ocelots and cheetahs, Patrick Aryee looks back over 11 million years of cat evolution, revealing how they became the most successful family of predators on the planet. Grrrr-eat!



15 DECEMBER

Stargazing Live Specials

BBC One/BBC Two, time TBC

TIM PEAKE WILL be appearing on our screens more often than the Queen and Del Boy combined this festive season. In these *Stargazing Live* specials presented by Prof Brian Cox and Dara O Briain, you'll be able to follow Tim's progress as he undertakes his journey of a lifetime. Watch live as he launches into space at around 11:00 GMT and then arrives at his new home six hours later.

19 DECEMBER



Winter Wonderland

Nat Geo Wild, 2pm

AS YOU SNUGGLE up indoors this winter, spare a thought for our wild chums. Some sleep through the cold, but others have to face the elements head on. This one-off Christmas special features moose, deer and, best of all, a beaver building a home for his family.

22 DECEMBER

Dino Day

Eden, all day

ALL THROUGH CHRISTMAS, Eden will be broadcasting back-to-back episodes of the best in nature, wildlife and space documentaries. Dino Day looks like a particular highlight, with *Ice Age Giants*, *Dino Hunt*, *Living With Dinosaurs*. Looks like we're not going to be leaving the sofa much that day...



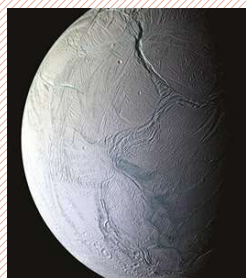
LISTEN

Space Week

BBC World Service, 12-18 December



FIND OUT WHAT it's like to live on the ISS, why Saturn's moon Enceladus is now considered the most intriguing body in our Solar System, and why future wars could be fought 'off-planet'.



Enceladus: it's plain, but there's a lot going on under the surface



TOUCH

SMARTPHONE & TABLET APPS
WITH KATE RUSSELL

DNA Play

iOS 6.0 or later, iPhone/iPad/iPod Touch, Android 2.3.3 or later, Avokiddo, £2.29



KIDS LOVE MONSTERS, as long as they aren't hiding under the bed! *DNA Play* is an open-ended creative experience that uses monsters to teach your little ones about DNA, genes and mutations. In this beautifully illustrated app they can drag, drop and tap DNA strands to tweak and create over 200 billion

different little critters. As they do so, the monsters will undergo strange mutations in real time, inspiring young minds and sparking conversations about what makes us who we are.

Tree Id

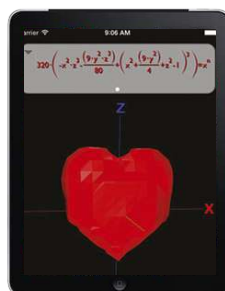
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IS YOUR CHRISTMAS tree a Norway spruce? Or perhaps you plumped for a Lodgepole pine this year? What do you mean, you don't know? It's easy to find out – just download *Tree Id*, a handy app for identifying British trees, quite literally 'in the field'. Search for a species by name, or run the identification quiz to describe aspects of the tree and choose a match from the resulting pictures. The database covers all native and naturalised wild tree species in the British Isles, as well as some plantation and parkland species. You can also record your finds in the sightings database.

Quick Graph

iOS 7.0 or later, iPhone/iPad/iPod Touch, KZ Labs, free



FOR STUDENTS STRUGGLING with abstract mathematical concepts, geometry and calculus, a graphing calculator can be a lifesaver. *Quick Graph* provides a comprehensive and powerful tool to enter, edit, and visualise complex equations in 2D and 3D, as well as displaying mathematical notation. Making full use of the iPhone's pinch-and-swipe interface, it's easy to manipulate the data to make better sense of it. For access to

more complex tools such as implicit graphs and tracing, you can download the advanced version of the app for £1.49.

KATE RUSSELL is a technology journalist and *Click* presenter



VISIT

EVENTS & EXHIBITIONS

WITH JHENI OSMAN



UNTIL 3 JANUARY

Destination Space: Astronauts Show

Life Science Centre, Newcastle, life.org.uk

COULD YOU GIVE Matt Damon a run for his money and survive in space? From wearing spacesuits to food and exercise, this show explores life as an astronaut. Included in entry price for venue.

9 JANUARY

2016 Scottish FameLab Final

National Museum of Scotland, Edinburgh, times TBC, free, nms.ac.uk

WITNESS SCIENCE COMMUNICATORS presenting their ideas in three minutes, and decide who will win a place in the FameLab UK Final.



9 JANUARY

Silver Screen Sci-Fi Showing

Royal Observatory Greenwich, London, 6pm-8:15pm, £8, rmg.co.uk

WATCH THE ANIMATED film *Renaissance*, set in dystopian Paris, then enjoy a talk from an astronomer about the science behind it.

UNTIL 10 JANUARY

Child's Play: Toys And Technology

National Museum of Scotland, Edinburgh, free, nms.ac.uk

DEAR SANTA, PLEASE can I have a hoverboard, spacesuit and a pet dinosaur... From scooters to swagways, discover how toys have changed over the decades and how they could evolve.

12 JANUARY

100th Anniversary Of The Election Of Women To The RAS Fellowship

Royal Astronomical Society, London, 6pm-7pm, ras.org.uk, booking essential

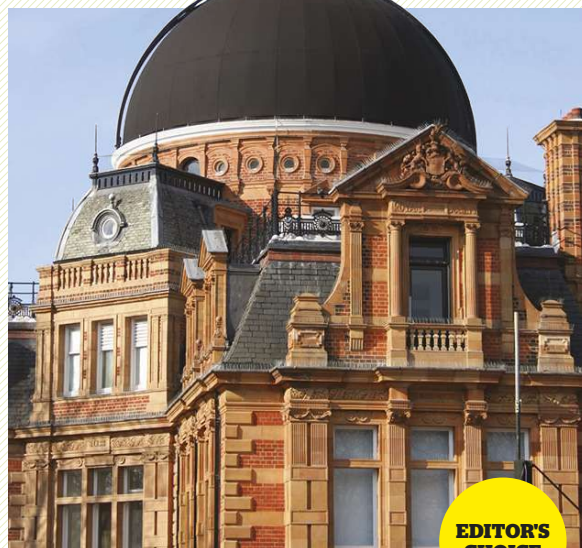
THIS TALK TAKES a brief look at the first female RAS fellows.

15-17 JANUARY

London Model Engineering Exhibition

Alexandra Palace, London, £11, londonmodelengineering.co.uk

EMBRACE YOUR INNER nerd! At this model exhibition, get hands-on and watch demos with robots, steam locomotives and planes.



EDITOR'S CHOICE

5 JANUARY - 9 FEBRUARY

Astronomy Courses

Royal Observatory Greenwich, London, 7pm-9pm, Tuesdays, £78, rmg.co.uk



NAIL THE LOCAL pub quiz by genning up on your cosmic knowledge. Learn your Owl Nebula from your Eagle Nebula with the Introduction to Astronomy course. Or, if you're after something more hands-on, either try the Practical Observing for Beginners or the more advanced Digital Astrophotography with a Telescope.

DATES TBC

Crime Scene Live

Natural History Museum, London, £60, booking required, nhm.ac.uk

MOVE OVER MR Cumberbatch, there's a new breed of Sherlocks in training. At this popular monthly event, be a CSI for a night and help forensic experts solve a murder mystery.



UNTIL 28 FEBRUARY

Enduring Eye: The Antarctic Legacy Of Sir Ernest Shackleton And Frank Hurley

Royal Geographical Society, London, free, rgs.org

GRAB THE CHANCE to see this exhibition of extraordinary photographs that document the lives of the men on Ernest Shackleton's harrowing expedition in Antarctica.

UNTIL 30 JUNE

Cycle Revolution

Design Museum, London, £13, designmuseum.org

NO NEED TO get your Lycra on to enjoy this exhibition, which reveals how the design and innovation of bikes will evolve in the future.



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Visual
feasts



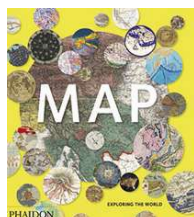
IN SOME WAYS, making an art book about *2001: A Space Odyssey* is cheating – Kubrick's masterpiece is one of the most beautiful films ever made. But this book doesn't just rely on the source material. It pulls together images, interviews and testimonies that will make you love the film even more. From detailed line drawings to contemporary NASA concept art, there's a new perspective on almost every page. And though the book's monolith shape might seem like a gimmick, the gatefold pages add an extra dimension as you open them out. Like the film, this book has a touch of magic.

DANIEL BENNETT (Acting Editor)

Map

Phaidon H £39.95

FROM ANCIENT ENGRAVINGS of the sea to the modern infographics used by, er, science magazine editors, this inspirational book is stuffed with attempts to document the world – proof that maps have always been something of a human obsession.

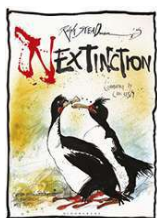


Nextinction

Ralph Steadman and Ceri Levy

Bloomsbury H £35

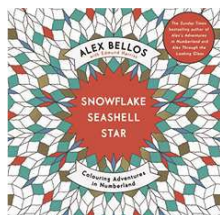
NEXTINCTION IS SOMETHING of a rarity: a truly original take on popular science. Love them or hate them, Ralph Steadman's vivid cartoons bring out the character of these endangered birds in a way that photography and other illustrations can't match.



Snowflake, Seashell, Star: Colouring Adventures In Numberland

Alex Bellos with Edmund Harriss

Canongate, P £12.99



COLOURING BOOKS ARE one of this year's hot trends: something to do with mindfulness, apparently. Alex Bellos adds some credibility to the pursuit with this maths-inspired colouring book.

Moonfire

Norman Mailer

Taschen H £13

History
of science



IN 1969, AMERICAN literary giant Norman Mailer covered the Apollo 11 Moon landings for *Life* magazine. In 1970, his articles were collected into a book called *Of A Fire On The Moon* and now in 2015, a condensed version of that book is republished by Taschen, complete with hundreds of new photographs, as *Moonfire*.

The 1,969 limited-edition copies that came with a signed photograph of Buzz Aldrin have all sold out – despite a price tag of \$1,800 – but this book's combination of startling photography and Mailer's engaging, free-ranging prose is still hard to beat. A gift that will delight the artistically minded and tantalise those of a literary bent as much as it will enthrall spaceflight buffs.

RUSSELL DEEKS (Contributing Editor)

The Great Scientists In Bite-Sized Chunks

Nicola Chalton & Meredith MacArdle

Michael O'Mara Books H £9.99



A POTTED HISTORY of 2,500 years of scientific endeavour, told through brief summaries of key breakthroughs and the men and women behind them. It's broken down into seven themed chapters: astronomy, mathematics, physics, chemistry, biology, medicine, and geology and meteorology.

Crucial Interventions

Richard Barnett

Thames & Hudson H £19.95

A HISTORY OF 19th Century surgery complete with some very graphic illustrations. They may only be line drawings but even so, this isn't one for the faint-hearted. You have been warned!



Madness In Civilization

Andrew Scull

Thames & Hudson H £28

AN IN-DEPTH ACCOUNT of how mental health has been regarded and 'treated' over the centuries, from ancient Greek ideas about 'humours' to current controversies. At over 400 pages, it's quite a serious tome, but riveting all the same.



The Science Of Everyday Life

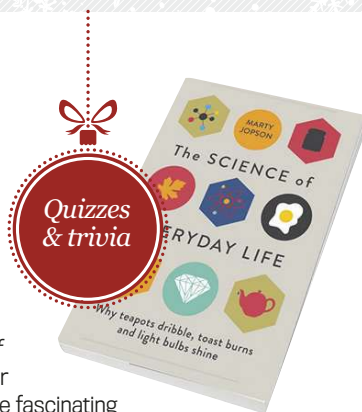
Marty Jopson

Michael O'Mara Books  £12.99

MARTY JOPSON IS resident scientist on BBC One's *The One Show*. In *The Science Of Everyday Life*, he takes a tour around the home to reveal the fascinating biology, chemistry and physics behind the stuff we use every day. Have you ever wondered why chillies are a different 'hot' to mustard, or why wine goes off? Or why your fingers and toes wrinkle in the bath? This book has the answers.

Perhaps more importantly, it covers that most British of problems: a dribbly teapot. The avid tea-drinkers of the *Focus* team pored over the solution to this conundrum and have been happily enjoying dry desks ever since.

Alice Lipscombe-Southwell (Production Editor)



The Creeping Garden: Irrational Encounters With Plasmodial Slime Moulds

Jasper Sharp and Tim Grabham

Alchimia  £16.99

IF YOU GO down to the woods today, look out for strange, oozing life forms clinging to trees – chances are it's a slime mould. Neither plant nor animal, slime moulds usually exist as single-celled organisms that feed on bacteria, yeasts and fungi. But when food is scarce, they congregate and move as a single, crawling mass, like something in a horror film. *The Creeping Garden* accompanies a documentary of the same name, and with beautiful photos and interviews with artists and scientists who work with slime moulds, it's a fascinating insight into these bizarre creatures.

James Lloyd (Editorial Assistant)



How Many Moons Does The Earth Have?

Brian Clegg

Icon Books  £6.99

THIS FASCINATING READ from regular *Focus* contributor Brian Clegg can either be enjoyed as a quiz with rounds, or as a simple trivia book. Find out why cooked meat is brown, why Father Christmas sets his watch by Big Ben, which part of the tongue houses salt-detecting taste buds and much more.

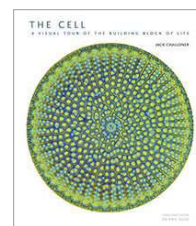


The Cell: A Visual Tour Of The Building Block Of Life

Jack Challoner

Ivy Press  £19.99

CELLS ARE THE basic units of every living thing, but for the most part they go about their daily business unnoticed by we humans. Explore the life and death of these miniature molecular machines in this informative book, which is chock-full of gorgeous microscopy images.



The All-New University Challenge Quiz Book

Steve Tribe

Quadrille  £12.99

FIND YOURSELF SMUGLY answering the questions on *University Challenge*? This book includes 1,800 questions from the long-running BBC quiz show, offering you the chance to unleash your inner Paxman and pit yourself against your friends. Just don't come crying to us when the arguments break out.

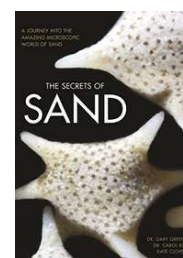


The Secrets Of Sand

Gary Greenberg, Carol Kiely and Kate Clover

Voyageur Press  £17

TO THE NAKED eye, sand can be beige and boring. As soon as you put it under a microscope, though, it becomes a multicoloured treasure trove of rocks, shells and skeletons. From the tropical coasts of Hawaii to the desolate plains of the Moon, sand comes in all shapes and sizes. You'll never look at Skegness in the same way again...

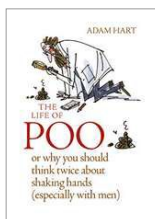


The Life Of Poo

Adam Hart

Kyle Books  £12.99

ISN'T IT TIME we stopped being squeamish about our toilet habits? BBC's Adam Hart delves into the world of poo and bacteria, revealing some startling truths about our bodies. While it's written in a light-hearted way, *The Life Of Poo* is flush with cutting-edge science that will leave you satiated. In fact, it could very well be the perfect toilet book...



The Snowflake: Winter's Frozen Artistry

Kenneth Libbrecht and Rachel Wing

Voyageur Press  £15

AS YOU WAIT to see whether this Christmas will be a white one, curl up with this visual treat. As well as being a snowflake photographer, Kenneth Libbrecht is also a snowflake physicist – probably the 'coolest' job title in the world!



Natural Histories

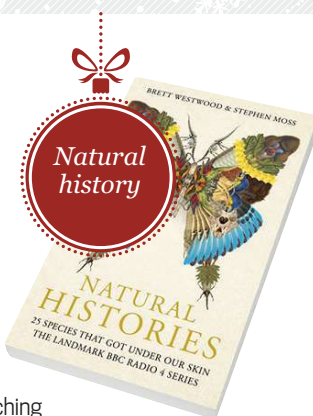
Brett Westwood and Stephen Moss

John Murray  £20

ADAPTED FROM THE BBC Radio 4 series of the same name, this entertaining and often beguiling book is split into 25 succinct chapters, each taking an animal-related object from London's Natural History Museum as a launching point for a wide-ranging investigation into human nature and the natural world.

Along the way we discover why butterflies were once thought to be evil, and what happened when a pipe-smoking, gin-drinking mandrill paid King George IV a social visit. The lively writing, enlightening anecdotes and frequent bursts of humour make this the ideal source of conversation topics if you run out of things to say while visiting the relatives.

JASON GOODYER (Commissioning Editor)

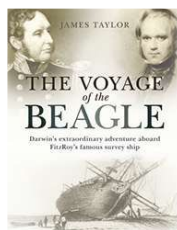


The Voyage Of The Beagle

James Taylor

Bloomsbury  £18.99

THERE HAVE BEEN countless books written about Charles Darwin's time touring the globe on the HMS Beagle – we even had two with exactly the same title to choose from when picking books for this round-up! But it's the inclusion of sumptuous illustrations and watercolours produced by the numerous artists that accompanied him on his historic journey that makes this one a standout.

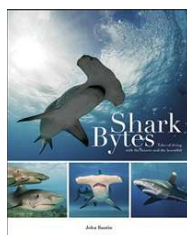


Shark Bytes: Tales Of Diving With The Bizarre And The Beautiful

John Bantin

Fernhurst Books  £17.99

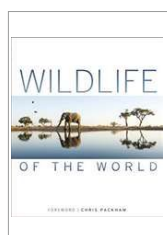
IF YOU'VE EVER fancied diving with sharks but have never quite been able to pluck up the courage to do it, this could be the book for you. Diving expert John Bantin shares his experiences of dozens of dives with everything from hammerheads to dugongs, each illustrated with stunning close-up photography.



Wildlife Of The World

Dorling Kindersley  £25

THOUGH IT'S A little too big to squeeze into the average stocking, this encyclopaedic tome is likely to keep any animal lover occupied over the festive season. It's jam-packed with facts, photos and infographics detailing the lives and habitats of countless birds, bugs and mammals, and will no doubt be easy to dip in and out of between glasses of sherry and mince pies.



Utterly Amazing Human Body

Robert Winston

Dorling Kindersley  £14.99

MY YOUNG DAUGHTERS were fascinated by this wonderful book explaining how their bodies work. Each fact and picture we looked at together was greeted with a 'wow' or a 'yuck', and they were still looking through it long past bedtime.

The fact that it's packed with projects to try at home all adds to the fun. There's a good mixture of interesting facts and easy-to-understand graphics, and the pop-up elements and moving parts make explaining the body to children of all ages an easy and fun activity. This is the sort of book that could easily spark a lifelong interest in the biological sciences.

JAMES CUTMORE (Picture Editor)



100 Facts: Stars & Galaxies/Space Travel/Solar System

Miles Kelly  £6.99 each

THESE BOOKS DO exactly what they say on the cover, with 100 fascinating scientific facts crammed into a series of exciting and well-presented books. Adults and older children alike will have fun swotting up on all things space-related, from black holes to planets via comets, asteroids and what astronauts have for breakfast.

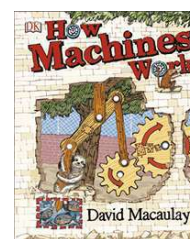


How Machines Work

David Macaulay

Dorling Kindersley  £14.99

FOLLOW THE ADVENTURES of Sloth and Sengi (a species of elephant shrew from Tanzania) as they learn all about mechanics while trying to escape from the zoo. This wonderfully constructed mixture of intricate flaps and moving elements – think of it as a pop-up book on steroids – is guaranteed to keep your little ones entertained as you polish off the rest of the Christmas cake.

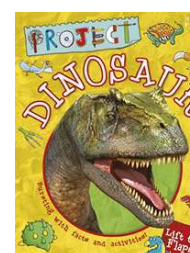


Project Dinosaur/Project Body

Steve Parker/John Farndon

Miles Kelly  £9.99 each

A GREAT SERIES of books for the science-mad child in your life, full of facts, informative drawings and fun project ideas that you can make at home and enjoy together. My personal favourite was the make-your-own fake mucus – I guess that's what being brought up on *Fungus The Bogeyman* does for the mind.



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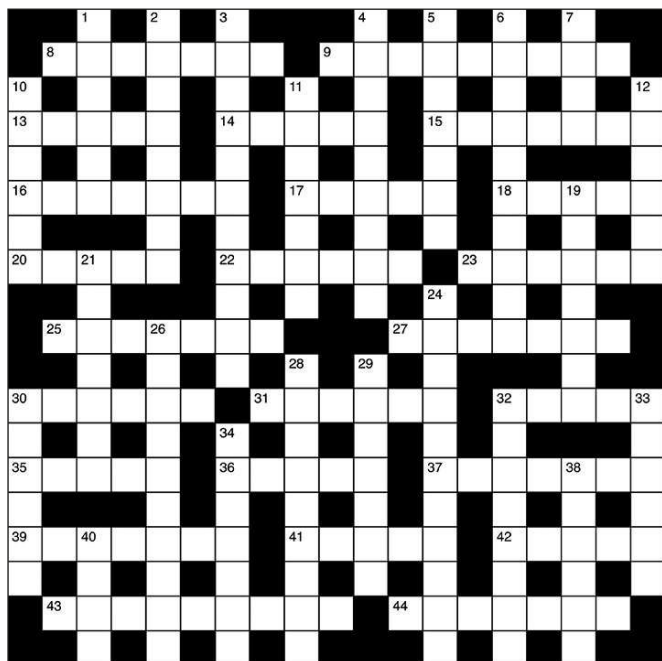
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FOCUS CROSSWORD No 185

More online Solve puzzles from BBC Only Connect hosted by Victoria Coren Mitchell at bbc.in/1vCOzuY



ACROSS

- 8 Firm wind on a bunch of petals (7)
- 9 Bishop takes iodine, only to beat cyclic pattern (9)
- 13 America has time for employment (5)
- 14 Doctor has car fitted with lens (5)
- 15 Boast at pub of means of entry (7)
- 16 Viewer has to run to find fastening (7)
- 17 Cries audibly for some material (5)
- 18 Home has a creepy sound (5)
- 20 Proportion of auction gets cancelled, initially (5)
- 22 Cat has a right to an air passage (6)
- 23 Masseter, say, gives strength (6)
- 25 Garnets displaying type of quark (7)
- 27 Element involved in scare (7)
- 30 Nose with hesitation to find tree (6)
- 31 Graduate has advantage of a monkey (6)
- 32 Something valuable, as arranged (5)
- 35 Art is performed for part of the flight (5)
- 36 Laugh about desire for predator (5)
- 37 Very many directions put me off first (7)
- 39 Old key turned into part of crystal (7)
- 41 A rota devised for vital supplier (5)
- 42 Fish in the corner (5)
- 43 To me, lager can be used as a sensitivity gauge (9)
- 44 Allspice to top mine off (7)

DOWN

- 1 After party, wise man has some pills (6)
- 2 Dullard hears total scientific opening (8)
- 3 To my logical reckoning, it's a study (11)
- 4 I contain a form of plant (9)
- 5 Fellow has framework of ferns (7)
- 6 Upset, honey, at forming part of a triangle (10)
- 7 Fish around the centre (4)
- 10 Force to take turn in gown (6)
- 11 Salad ingredient can be a shipping hazard (7)
- 12 Reporting cheeses, that's easy (6)
- 19 Cries OK about range (7)
- 21 I can't change one to a sea anemone (7)
- 24 Ran curtains off with an atomic number greater than 92 (11)
- 26 Bear hybrid has share of abnormality (10)
- 28 Race leader has a cardiac device (9)
- 29 Arc travelled in European sailing vessel (7)
- 30 Nut points to money first (6)
- 32 Article about the lab takes pressure from every character (8)
- 33 Intellect without second fiddle (6)
- 34 Having lost weight, being solvent (7)
- 38 Rowers reach hard part (6)
- 40 Temperature that can be caught (4)

SOLUTION TO CROSSWORD No 182

Glenys Robinson, Roberta McCutcheon, Margaret Baxter, Andrew Holmes and Julia Raiswell each solved issue 286's puzzle and receive a copy of *Idris Elba: No Limits* (Go Entertain, £9.99)



WIN! ULTIMATE STAR WARS

The first five correct solutions drawn will each win a copy of *Ultimate Star Wars* (Dorling Kindersley, £35). Entries must be received by 5pm on 7 January 2016. See below for more details.



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Post entries to *BBC Focus Magazine*, Christmas 2015 Crossword, PO Box 501, Leicester, LE94 0AA or email a scan of the completed crossword or a list of answers to christmas2015@focuscomps.co.uk by 5pm on 7 January 2016. Entrants must supply name, address and phone number. Immediate Media, publisher of *BBC Focus Magazine*, may contact you with details of our products and services or to undertake research. Please write 'Do Not Contact' on your email or postal entry if you do not want to receive such information by post or phone. Please write your email address on your postal entry if you would like to receive such information by email.

TERMS & CONDITIONS

Entrants must be UK residents (inc Channel Islands) aged 18 or over. Immediate Media employees are not eligible to enter. By entering participants agree to be bound by these terms and conditions and that their name and county may be released if they win. Only one entry permitted per person. No responsibility is accepted for lost, delayed, ineligible or fraudulent entries. Entries received after the closing date will not be considered. Immediate Media (publisher of *BBC Focus Magazine*) will only ever use personal details for the purposes of administering this competition unless you permit

otherwise. Read more about the Immediate Privacy Policy at www.immediatemediaco.uk/privacy-policy. The winning entrants will be the first correct entries drawn at random after the closing time. The prize and number of winners will be as shown above. The winners will be notified within 30 days of the closing date by post. Immediate Media's decision is final and no further correspondence relating to the competition will be entered into. If the winner cannot be contacted within one month of the closing date, Immediate Media reserves the right to offer the prize to a runner-up.



MY LIFE SCIENTIFIC

SIR MARTYN POLIAKOFF

Research Professor at Nottingham University

My grandfather invented the volume control you get on radios as well as the induction loop that is still used in theatres to help people with hearing difficulties. My father was a physicist too. Even when I was young, he had already decided that I would follow in his footsteps and become a scientist.

I've always worked obsessively. My parents went to my school to complain that I was working too much. But the teachers just laughed and said they wished this problem was more common.

I have two jobs at the moment. I'm Research Professor at Nottingham University, and Foreign Secretary and Vice President of the Royal Society – each of them takes 60 per cent of my time!

Sadly, I have little spare time for hobbies. But I do like reading: biographies and history mainly. My father was Russian, and although I'm not a native speaker, I do try to speak some Russian most days.

Research is almost an addiction. The planet's population is growing. We have to find cleaner, greener ways of making the chemicals that we need. I'm particularly interested in how to make reactors where light is used to drive chemical reactions with less waste. One reactor is based on an idea I had while I was in the bath. One of the nice things about being a scientist is that you discover new things which excite you.

I look a bit like Einstein. There's a portrait of him when he was young in the Dining Room at the Royal Society. When I show it to people, I tell them that it's a portrait of Einstein before he looked like me!

The Periodic Table of Videos is an extraordinary project. We've made 570 YouTube videos that have attracted millions of hits. I get emails almost daily from fans across the world and I often get recognised when I'm out and about.

In 50 years or so, one-third of the world's population will be living in Africa. They will face huge problems with soil erosion, water shortages and feeding the growing population. One has to have faith that science will overcome these problems. So I'm very keen to promote science in Africa. African countries need to have their own research scientists on the front line from where they can mobilise the international community.

It's a real privilege to work with so many young people. It's rather like Peter Pan. My co-workers come and go, but they always stay a similar age. I think that helps me to stay young.

I supplied a few lines of dialogue for my brother Stephen's play. It's called *Blinded By The Sun*, and was performed at the National Theatre in 1996. I was the only person in audience who laughed at the word 'hexafluoro-isopropanol'. ■

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